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SCIENCE

FEBRUARY 6, 1953

VOLUME 117 NUMBER 3032

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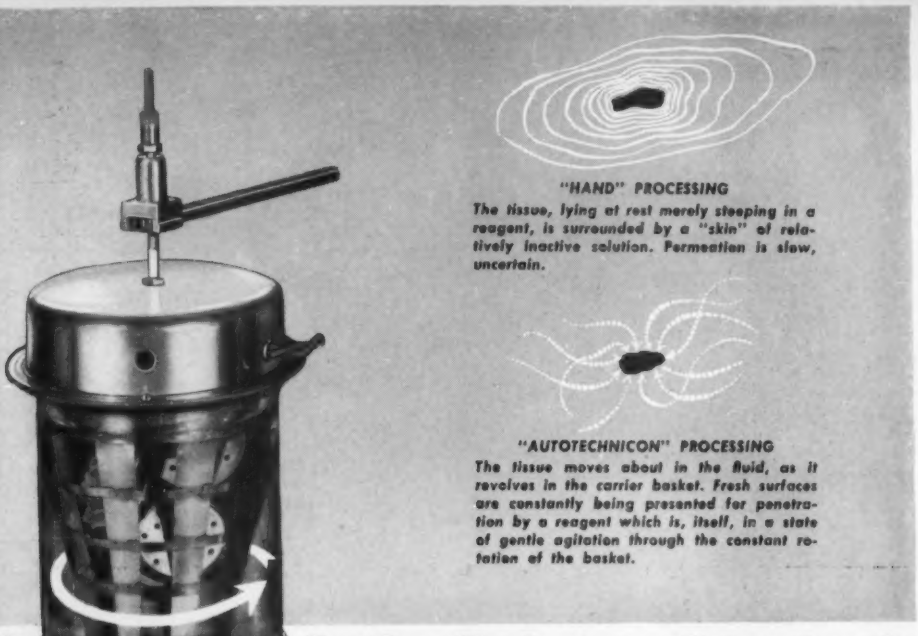

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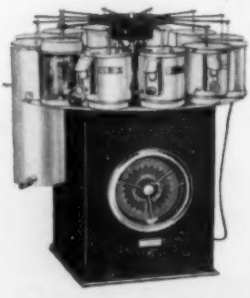

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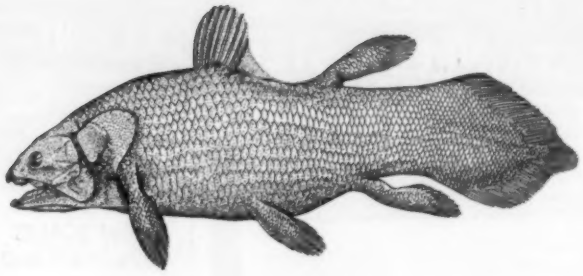

the one that got away . . .

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Chief eluder of all time—and therefore chief bane to anglers and bored listeners alike—would definitely appear to be *Latimeria*, a crossopterygian. Only a single specimen has ever been caught (and judging from its appearance, that specimen might well have been caught in a wringer).

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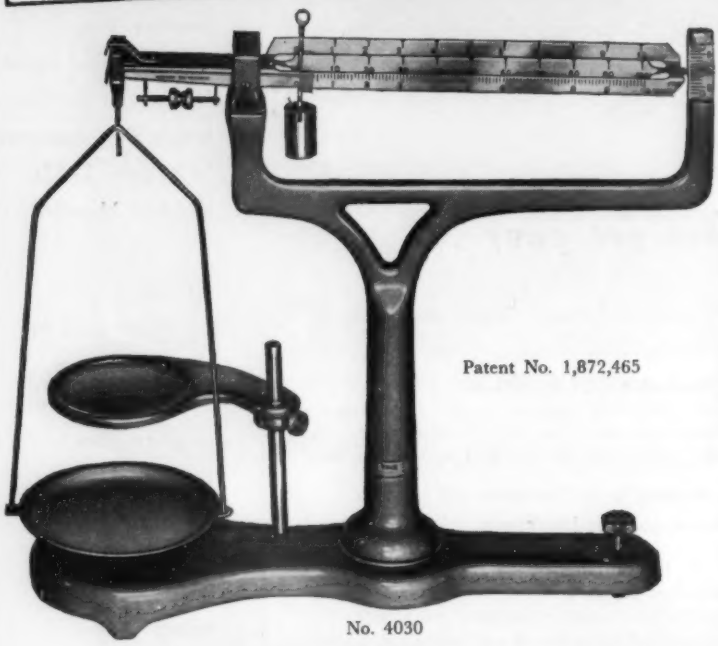

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Jet Mill Grinding

JET mill grinding is a mechanical method of comminution used for reduction of particles into superfine subsieve sizes of particle range. By this is meant maximum sizes of 20–10–5, or less, microns diameter of the particles. The possibility of producing, on a commercial scale, very small particle sizes depends, of course, on the friability of the materials. In general, rubbery, some fibrous, or very resilient materials cannot be handled. Agglomerates of certain materials, such as metal powders, can only be dispersed.

One of the first jet mills for commercial use, the Micronizer, was introduced in the early thirties and has since found widespread use in the grinding of minerals, pigments, and foodstuffs, and even such antibiotics as penicillin and streptomycin. Later types included the Reductionizer and Fluid Energy Reduction Mill, and a new type, the Jet T-Mill. All these mills grind and classify within a continuous chamber.

The older mills use the same principle, passing the material past a series of jets, which introduce fluid streams of high energy into the pulverizing chamber. The applied fluid is transformed into velocity head when it expands to atmospheric pressure within the grinding chamber. Application of the fluid jets causes high-speed rotation of the contents of the chamber, which consist of a relatively small circulatory load of material being acted upon and entrained in the gaseous fluid. No heat is generated in the mill during the grinding process.

The velocity of the gas emitted from the jets may be as high as 2000–3000 feet per second at the nozzle tip, and the load velocities within the mill chamber may vary from 150 to over 400 feet per second. The fluid energy is usually compressed air or superheated steam. Air consumption varies between 15 and 20 cfm to 1500–2000 cfm at pressures of 50–150 psi gauge. Superheated steam may vary between 100 and 5000 lbs/hr, usually at pressures of 75–225 psi gauge. Superheat of air or steam will dry the materials processed.

Except for the new Jet T-Mill, which is a simplified but efficient mill using only two opposed nozzles, which meet head on in a small tubular grinding chamber, the mills employ from four nozzles, in small types, to sixteen in the larger mills.

Methods of controlling particle size are basically dependent upon (1) rotational speed, (2) gas flow, (3) flow of feed material within fairly close limits, and (4) shape and proportions of grinding and classification chambers. Control of the first and second factors is usually accomplished by adjusting the rate of feed or gas pressure and the temperature. Flow of feed material depends on the type of feeder mechanism used. The fourth factor is usually varied experimentally, to adapt mill construction to the processing of a particular product.

In general, the energy cost of grinding to very low micron sizes will range from $1.00 for precipitates or claylike materials, up to $10.00 per ton, and higher, for the less grindable materials. Other materials, such as limestone, will cost about $3.00–$5.00 per ton, but even on some one type of material the range may be wide, depending upon the requirements with regard to the maximum permissible particle size. These figures are energy costs, not over-all grinding costs. Other items of expense are dependent upon scale of operation and local factors, hence gross cost figures cannot be given.

With today's increasing demand from industry and from science for finer particle sizes, jet mills will be widely used in superfine grinding, and their potential importance in the chemical industry has just begun to be appreciated.

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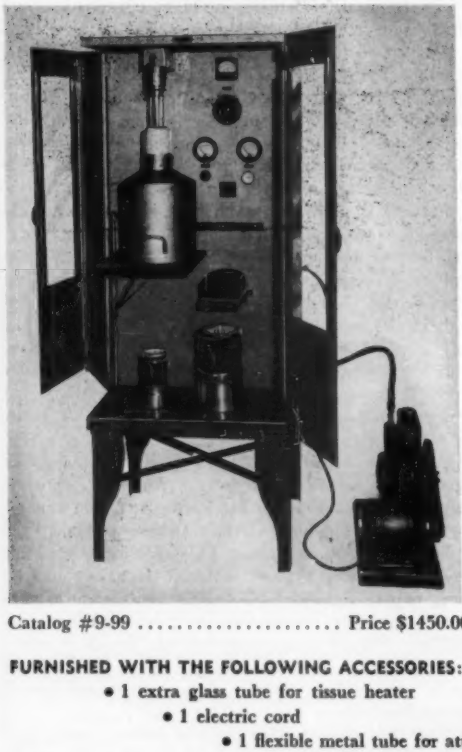

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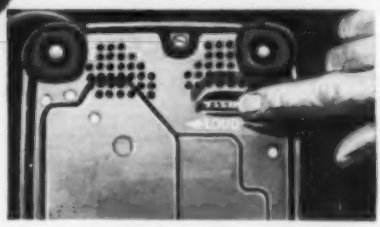

Adjustable volume control on bottom of new telephone permits subscriber to set it to ring as loudly or softly as he pleases. Ring is pleasant and harmonious, yet stands out clearer.

For years the telephone you know and use has done its job well—and still does. But as America grows, more people are settling in suburban areas. Telephone lines must be longer; more voice energy is needed to span the extra miles.

Bell Telephone Laboratories developed a new telephone which can deliver a voice ten times more powerfully. Outlying points may now be served without the installation of extra-heavy wires or special batteries on subscribers' premises. For shorter distances, the job can be done with thinner wires than before. Thus thousands of tons of copper and other strategic materials are being conserved.

The new telephone shows once again how Bell Telephone Laboratories keeps making telephony better while the cost stays low.

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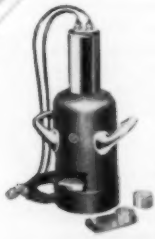

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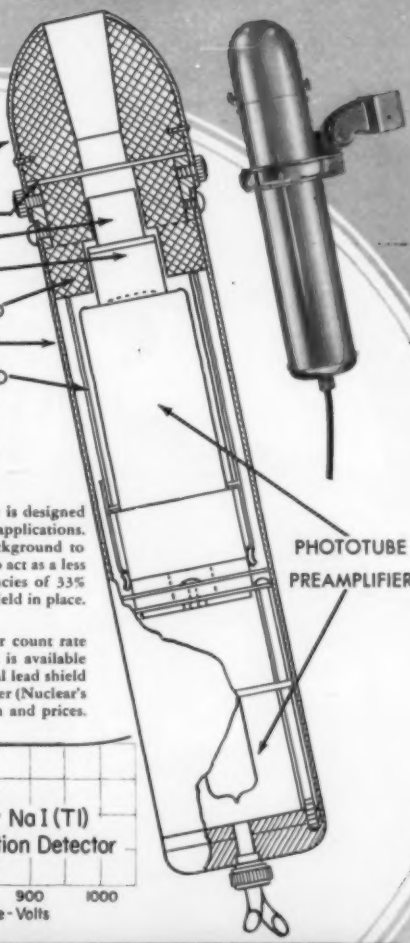

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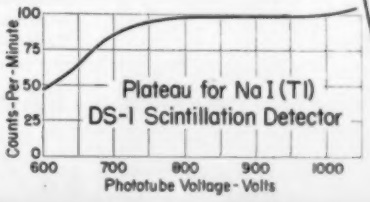

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Properties of Liquid Helium 3

Bernard M. Abraham, Darrell W. Osborne, and Bernard Weinstock
Argonne National Laboratory, Lemont, Illinois

THE DISCOVERY of He^3, the rare stable isotope of helium, by Alvarez and Cornog in 1939, was of considerable interest to low temperature physicists, because it presented a possible test of the theory that many of the remarkable properties of liquid He^4 are due to the existence of an even number of fundamental particles in the He^4 atom. According to this theory the behavior of liquid He^3, with an odd number of fundamental particles in the atom, would be expected to be quite different from that of liquid He^4. The present article summarizes the low-temperature research on He^3 and its significance in the liquid helium problem.

Liquid He^4. Before the methods of obtaining He^3 and the experimental work performed with it are described, a brief account will be given of some of the properties of liquid He^4 and of the theory that stimulated the study of He^3. More detailed accounts of the properties and theories of liquid He^4 may be found elsewhere (*1–3*).

Between its critical point, 5.2° K, and 2.19° K liquid He^4 exhibits no unusual properties, with the exception that its viscosity decreases slightly as the temperature decreases. At 2.19° K (the "lambda-point") a transition to a new liquid phase with many unique properties occurs. This phase is called He II to distinguish it from He I, the liquid phase that is stable above the lambda-point. The transition takes place without a latent heat or a volume change and hence is a second-order transition, in contrast to the usual first-order phase transitions such as vaporization or solidification. The term lambda-point was suggested by the similarity of the shape of the heat capacity curve near this temperature to the Greek letter λ.

The properties of He II have caused it to be termed a superfluid. Its viscosity as determined by the measurement of the flow through fine capillaries becomes vanishingly small as the temperature is lowered. Furthermore, the heat conductivity becomes abnormally large—under suitable conditions a thousand times that of copper at room temperature. Perhaps an even more remarkable property is the propagation of heat pulses through He II by a wave motion, which is called "second sound," by analogy with the transmission of pressure differences in ordinary sound. Still another characteristic of He II is the mobile film that apparently defies gravity. For example, the film flows up over the rim of an empty beaker partially immersed in a He II bath until the liquid levels inside and outside the beaker are equalized. Finally, in contrast to all other substances, He^4 remains liquid when cooled under its own vapor pressure to absolute zero, and at that temperature it requires a pressure of 25 atmospheres for solidification.

It has been possible to correlate many of these phenomena by assuming that He II is composed of two interpenetrating fluids, a normal and a superfluid (*4*). The former, as the name implies, is assumed to be similar to an ordinary liquid, whereas the latter is assumed to have zero viscosity, zero entropy, and zero heat content. In this theory the relative amount of the normal and superfluid components is determined by the temperature, the fraction that is superfluid increasing rapidly from zero at the lambda-temperature to unity at 0° K. The flow through narrow channels is explained as being due primarily to the superfluid, which flows with zero viscosity, whereas the normal fluid is held back by viscous drag. The decrease of the viscosity as the temperature is lowered is due to the decrease in the proportion of the normal fluid. The mechanism of heat transfer is depicted as an internal convection of normal and superfluid, the former moving toward the cold zone and the latter toward the hot zone. This process, which occurs with much greater efficiency than ordinary heat conduction, results in the extremely high heat conductivity. Undoubtedly a major triumph of the two-fluid model was the prediction of second sound several years before its observation.

The two-fluid hypothesis, as first developed by Tisza (*4*), was inspired by a suggestion of F. London (*5*) that there is a connection between the lambda-transition in liquid He^4 and a peculiar condensation that can occur in a gas following Bose-Einstein statistics. In such a gas, starting at a characteristic temperature, T_0, the atoms begin to occupy the lowest energy state, and at 0° K all the atoms are in this state. At T_0 a maximum appears in the heat capacity of a Bose-Einstein gas; similarly there is a maximum in the heat capacity of liquid He^4 at the lambda-temperature. When the density of liquid He^4 is used in this gas model, T_0 is calculated to be 3.14° K, in reasonable agreement with the observed lambda-temperature, 2.19° K. It should be pointed out, however, that quantitative agreement is not to be expected, because the interactions between the atoms have been neglected in treating the liquid as a gas. In the development of the two-fluid theory, Tisza identified the superfluid with the atoms in the lowest energy state.

It is important to note that this condensation cannot occur in a system that follows Fermi-Dirac statis-

ties, because the latter permits only a small number of atoms to occupy the lowest energy state. The statistics followed by a system of weakly interacting identical atoms is simply determined by the number of fundamental particles in each atom. If the number is even, as in He^4, Bose-Einstein statistics is obeyed; if it is odd, as in He^3, Fermi-Dirac statistics is obeyed. No further information regarding these types of statistics is needed to appreciate their significance in the helium problem. Clearly, any theory that bases the behavior of liquid He^4 on Bose-Einstein statistics cannot apply to He^3. The comparison, then, of liquid He^3 with liquid He^4 offers a means of evaluating the importance of statistics in influencing macroscopic behavior.

Sources of He^3. The natural abundance of He^3 is very small, varying from about 1 ppm in atmospheric helium to about 0.1 ppm in gas well helium. Although its separation from natural sources seems to be a formidable task, significant quantities of helium containing as much as 4 per cent He^3 have been obtained. The principal technique that has been used for the separation is thermal diffusion, and enrichment methods that take advantage of the superfluid properties of He^3–He^4 solutions (to be discussed later) have also been employed.

Fortunately, it became possible to avoid this difficult isotope separation by making use of the following nuclear reactions:

$$Li^6 + n \longrightarrow H^3 + He^4 \qquad (1)$$

$$H^3 \xrightarrow{12.5\ yr} He^3 + e^- \qquad (2)$$

Tritium (H^3) is first produced by irradiating lithium with neutrons in a chain-reacting pile, as shown in Eq. (1). The tritium is easily separated from the He^4—for example, by diffusion of the tritium through a heated palladium thimble—and is then set aside to decay (Eq. [2]). Finally, the He^3 that has grown in is separated from the remaining tritium. The isotopic purity of the He^3 is limited only by the completeness of the initial separation of tritium from He^4. The preparation of He^3 by this method was first reported by A. Novick (*6*) in his determination of the half-life of tritium.

Liquefaction of He^3. The question of immediate interest, once pure He^3 was obtained, was whether it would liquefy. This question was raised because the attractive forces in He^4 are so weak that they are barely able to overcome the zero-point energy to form a liquid phase. In He^3 the attractive forces are the same, but the zero-point energy is larger as a result of the smaller mass, and therefore it seemed possible that He^3 might not liquefy. Notwithstanding, de Boer and Lunbeck (*7*) predicted the vapor pressure and the critical point of liquid He^3 on the basis of a quantum theory of corresponding states. Their predictions were in excellent agreement with the first measurements on liquid He^3 by Sydoriak, Grilly, and Hammel (*8*) and with the subsequent measurements by the authors (*9*).

TABLE 1

VAPOR PRESSURES OF LIQUID He^3 AND LIQUID He^4

T (°K)	P_{He^3} (mm Hg)	P_{He^4} (mm Hg)	P_{He^3}/P_{He^4}
1.0	8.7	0.12	72
1.5	50.7	3.59	14
2.0	152	24.2	6.3
2.5	334	78.5	4.3
3.0	618	183	3.4
3.35	890	293	3.0

A comparison of the vapor pressures of the two liquids at several temperatures is given in Table 1; the boiling points, critical constants, and molar volumes (*10*) are given in Table 2. It is interesting to note that the greater zero-point energy of He^3 causes the molal volume of liquid He^3 to be much greater than that of liquid He^4.

TABLE 2

PHYSICAL CONSTANTS OF LIQUID He^3 AND LIQUID He^4

	He^3	He^4
Boiling point (°K)	3.20	4.22
Critical temperature (°K)	3.35	5.20
Critical pressure (mm Hg)	890	1718
Molal volume at 1°K (ml)	38	27.6
Lambda-temperature (°K)	?	2.19

Flow properties of liquid He^3. After it had been established that He^3 would liquefy, the authors (*11*) made a search for superfluidity by comparing the flow rate of liquid He^3 with that of liquid He^4 through a narrow channel, or "superleak." The leak was constructed by shrinking a Pyrex glass capillary around a platinum wire of 0.005 in. diameter. On cooling, a narrow annular channel was formed because of the difference between the coefficients of expansion of the glass and the metal. By measuring the flow rate of

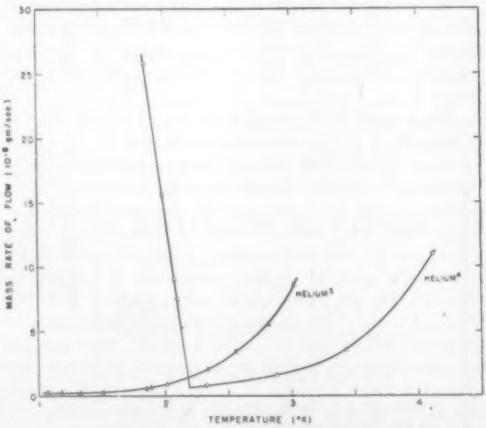

FIG. 1. Mass rate of flow of liquid He^3 and of liquid He^4 through a superleak, as a function of temperature.

helium gas through the leak at 4.22° K, the width of the channel was estimated to be 7×10^{-5} cm. The assembly was in the shape of a long U-tube supported vertically in a liquid helium bath, with the superleak constituting the lower 5 cm of one leg. The experiments were performed by condensing about 0.02 ml of liquid at the top of the leak and then permitting the liquid to flow through under its own vapor pressure. The amount of material flowing through the leak was observed as a pressure rise in a large bulb outside the helium bath. As shown in Fig. 1, the mass rate of flow of liquid He^4 was observed to decrease with temperature until the lambda-point was reached, and then to increase sharply with further decrease in temperature. On the other hand, the rate of flow of liquid He^3 under the same conditions decreased steadily as the temperature was lowered from 3.2° K to the lowest temperature attainable in the apparatus—1.05° K.

It was thus established that superfluidity does not occur in liquid He^3 down to 1.05° K. This temperature is probably low enough for the conclusion to be drawn that liquid He^3 does not become superfluid at any temperature, in agreement with the theory that the lambda-transition in He^4 is connected with Bose-Einstein statistics. The conclusion was further corroborated by an experiment of Daunt and Heer (*12*) with He^3–He^4 solutions, which will be described later. From their results they deduced that pure He^3 is not superfluid down to at least 0.25° K.

The viscosity of liquid He^3 has been obtained from measurements of the flow rate through the superleak under various pressure heads (*13*). It was found that the viscosity increases from a value of 22 micropoise at 2.8° K to 30 micropoise at 1.0° K. By comparison, the viscosity of He I decreases slightly from 33 micropoise at 5° K to 30 micropoise at 2.7° K and then more rapidly to 22 micropoise at the lambda-point, just as though the He^4 were anticipating the lambda-point. The fact that the viscosity of liquid He^3 increases with decreasing temperature is therefore believed to be further evidence for the nonexistence of a superfluid transition in He^3.

Solidification of He^3. The absence of superfluidity in He^3 raised the question whether He^3 would remain liquid at absolute zero. An examination of the melting pressure curve of He^4 seems to indicate that there would have been a triple point at 1° K if the lambda-point had not occurred. Instead, the melting pressure curve suddenly changes course at the lambda-point and then rapidly approaches a constant value of 25 atmospheres. It seemed possible, therefore, that liquid He^3, which has no lambda-point, might solidify under its own vapor pressure.

A schematic diagram of the apparatus used by the authors (*14, 15*) to determine the melting curve of He^3 is given in Fig. 2. The technique employed was the blocked capillary method used by Keesom to determine the melting pressure of He^4. As the pressure in the system was slowly raised by compressing the He^3 gas in the reservoir (*H*) with the hydraulic system

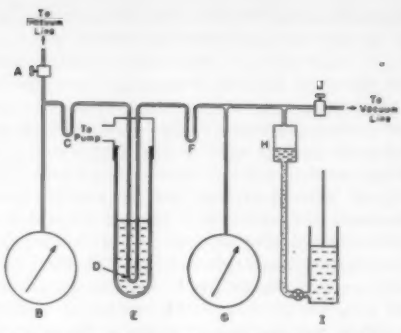

FIG. 2. Apparatus for the measurement of the melting pressure of He^3 (schematic).

(*I*), the two Bourdon gauges (*B, G*) read the same until solidification occurred. Then, because of the plug of solid that now blocked the capillary U-tube (*D*), gauge (*B*) remained constant at the melting pressure, whereas gauge (*G*) continued to increase. Conversely, as the pressure was lowered, the gauges became equal again at the melting pressure. For measurements between 1.5° K and 1.02° K the capillary U-tube was immersed directly in a bath of liquid helium (*E*) boiling under reduced pressure, and for measurements down to 0.16° K it was surrounded by a paramagnetic salt (ferric ammonium alum), which was cooled by adiabatic demagnetization.

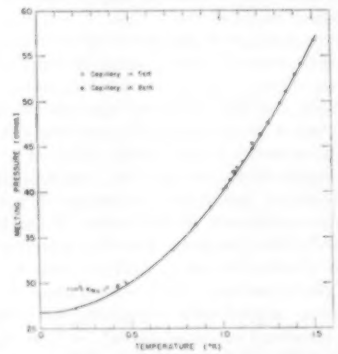

FIG. 3. Melting pressure of He^3 vs. temperature.

The results of both sets of measurements are plotted in Fig. 3. From 0.5° K to 1.5° K the data are represented by the equation

$$P = 26.8 + 13.1\ T^3 \text{ atm}, \qquad (3)$$

which is shown as the solid curve in the figure. Below 0.5° K the observed pressures approach a constant value of 29.3 atmospheres, but there is a possibility that the deviation of these points from Eq. (3) may be due to poor thermal contact between the capillary and the salt below 0.5° K. It is clear, however, that the melting pressure is at least 26.8 atmospheres at

absolute zero, and that He^3, like He^4, remains liquid under its own vapor pressure at absolute zero.

Nuclear alignment in He^3. Besides yielding information about the physical state of He^3 near absolute zero, the melting pressure curve can answer the question of nuclear alignment in the liquid. At high temperatures the nuclear spins in He^3 (equal to ½) are randomly oriented, and this disorder contributes to the entropy of both liquid and solid. At sufficiently low temperatures the spins may become aligned in a parallel or antiparallel arrangement, with a concomitant loss in the nuclear spin entropy. This effect would be absent in He^4, since it has no nuclear spin. Pomeranchuk (*16*) has predicted that, because of exchange forces effective in the liquid but not in the solid, this alignment will take place in the liquid near 1° K but not in the solid until 10^{-7}° K. According to his prediction the entropies of the liquid and solid become equal near 1° K, and below this temperature (down to 10^{-7}° K) the entropy of the liquid is less than that of the solid. Consequently, the melting pressure curve would have a minimum at 1° K and then rise as the temperature is lowered further. As was shown in Fig. 3, however, the experimentally determined melting pressures do not show a minimum, in disagreement with Pomeranchuk's prediction, and it can be concluded that nuclear alignment does not occur in the liquid down to 0.5° K. Further experimental work is needed to determine the shape of the melting pressure curve below 0.5° K, for it is still possible that nuclear alignment will occur at a lower, experimentally realizable temperature.

He^3–He^4 solutions. A discussion of He^3 is not complete without consideration of some of the properties of He^3–He^4 solutions. It will be possible to cover only the highlights of the extensive research with these solutions, but a more comprehensive treatment may be found in a recent review article (*17*).

It was suggested by Franck (*18*) that the He^3 in a He^3–He^4 solution would not participate in superflow and that an enrichment of He^3 could be obtained by making use of this property. The idea was first tested by Daunt, Probst, Johnston, Aldrich, and Nier (*19*) in a film flow experiment with atmospheric helium. A Dewar vessel, capped with a ground-glass plug, was partially immersed in liquid He II, so that the surface of the bath was below the cap. When energy was supplied to an electrical heater in the Dewar vessel, helium flowed in through the ground-glass joint solely by means of the mobile film. The helium that collected in the Dewar was shown by mass spectrometer analysis to have a He^3 concentration of less than 5×10^{-8}, as compared to the starting concentration of 1.2×10^{-6}. The result indicated that, in agreement with Franck's suggestion, He^3 does not partake of the superflow in the helium film and that it is indeed possible to enrich He^3 by taking advantage of this behavior.

Further evidence that the He^3 in liquid helium does not participate in superflow was obtained by Lane, Fairbank, Aldrich, and Nier (*20*). In their apparatus, shown schematically in Fig. 4, a heater (*H*) was placed in the interior of an inverted bulb (*B*), which communicated with the filling system through a glass capillary U-tube (*C*), a Kovar tube (*K*), and another glass capillary (*T*). The whole assembly was immersed in a bath of liquid helium contained in a Dewar (*D*), and then atmospheric helium was condensed in the bulb and U-tube to the level indicated. With the bath below the lambda-point, heat was supplied to the heater, and 10 minutes later a portion of the liquid was removed from the Kovar tube by evaporation. The sample thus obtained contained 50 per cent of the total quantity of He^3 in the system, and the concentration of He^3 in the sample was 130 times the original value. This observation is explained in terms of the two-fluid model of heat conduction as a "heat flush," in which the superfluid atoms move toward the heater, whereas the He^3 atoms move away from the heater in company with the normal fluid and thus concentrate in the Kovar tube.

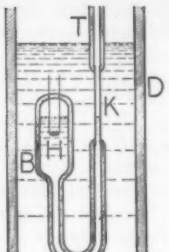

FIG. 4. Apparatus for the enrichment of He^3 in He^3–He^4 solutions by heat flush (schematic).

The heat flush technique has been incorporated in several of the procedures for the concentration of He^3 from natural sources. For example, Reynolds, Fairbank, Lane, McInteer, and Nier (*21*), starting with helium enriched to 0.01 per cent He^3 by thermal diffusion, have increased the concentration to 4 per cent. Using the heat flush method, Eselson and Lazarev (*22*) have produced helium containing 0.01 per cent He^3 from helium with an initial He^3/He^4 ratio of 5×10^{-8}, and Taconis has produced helium with .5 per cent He^3 from atmospheric helium with a He^3 content of 1.2×10^{-6}.

The postulate that He^3 associates only with the normal component of He^4 was extended further by Taconis, Beenakker, Nier, and Aldrich (*23*) in the interpretation of their vapor pressure measurements with a He^3–He^4 mixture containing 0.05 per cent He^3. The vapor pressure of an ideal solution is described by Raoult's law,

$$P = xP_3^\circ + (1-x)P_4^\circ, \qquad (4)$$

where P is the vapor pressure of the solution, P_3° and P_4° are the vapor pressures of pure He^3 and pure He^4, respectively, and x is the mole fraction of He^3 in the

solution. Offhand, one would expect that a mixture of two isotopes would form an ideal solution. However, the observed values of P below the lambda-temperature were always higher than predicted by Raoult's law, and the deviation increased as the temperature was lowered. A satisfactory explanation was obtained by assuming that the He^3 should be considered as dissolved only in the normal fluid and that x should be calculated without counting the superfluid component. As the temperature is lowered below the lambda-point, the amount of the normal fluid decreases, and hence x, the mole fraction of He^3 in the normal fluid, increases. This concept has been embodied in de Boer and Gorter's theoretical treatment (*24*) of the properties of He^3–He^4 solutions, and subsequent measurements have indicated that it is at least qualitatively correct.

In all the experiments with He^3–He^4 solutions described thus far, the He^3 content has been too small to cause a measurable change of the lambda-temperature of He^4. The lowering of the lambda-temperature by the addition of He^3 was first demonstrated by the authors (*25*) in another experiment with the superleak previously described. In these measurements the criterion for the occurrence of the lambda-transition in a solution was a break in the plot of mass rate of flow vs. temperature, similar to that shown for pure He^4 in Fig. 1. The results obtained in this way are shown as squares in Fig. 5. Daunt and Heer (*12*) extended the measurements to higher concentrations, using the appearance of the abnormal heat conductivity through the He II film to locate the lambda-temperatures. Their results, shown as open circles in Fig. 5, gave 0.38° K as the lambda-temperature of a solution with 89 per cent He^3, and, by extrapolation of the measured curve to 100 per cent He^3, they concluded that pure He^3 cannot be superfluid above 0.25° K. Also shown in Fig. 5 is a point for 1.5 per cent He^3 determined by Eselson, Lazarev, and Lifshits (*26*), who observed the temperature at which flow through the helium film begins. As a consequence of the decrease in lambda-temperature with increasing He^3 concentration, it is not possible to make pure He^3 by methods based solely on superfluidity. At temperatures that can be conveniently reached by pumping on liquid helium (about 1° K) the limit is approximately 60 per cent He^3.

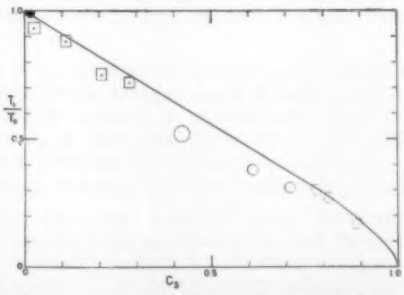

FIG. 5. Ratio of the lambda-temperatures of He^3–He^4 solutions, T_λ, to the lambda-temperature of pure He^4, T_0, as a function of the mole fraction of He^3, C_3. ● Eselson, Lazarev, and Lifshits (*26*); □ Abraham, Weinstock, and Osborne (*25*); ○ Daunt and Heer (*12*).

The apparent association of He^3 with only the normal fluid suggested that a He^3–He^4 solution below its lambda temperature might separate into two physically distinct liquid phases. The authors (*27*) have proved, however, that only a single liquid phase exists below the lambda-point by showing that the vapor pressures of a 20.3 and of a 25.5 per cent solution of He^3 in He^4 are different at all temperatures down to 1.04° K, well below the lambda-temperatures of both solutions. The proof follows from the phase rule, which would require the two solutions to have the same vapor pressure at a given temperature, if each had separated into two liquid phases. The existence of a single liquid phase above and below the lambda-point has the consequence that the lambda-transition in solutions is second order, as it is in pure He^4.

In conclusion it must be pointed out that, although the absence of superfluidity in He^3 shows that the lambda-transition in liquid He^4 is connected with the Bose-Einstein statistics, the theoretical explanation of the properties of liquid helium is far from complete. No mention has been made of Landau's (*28*) theory of liquid helium, which does not depend on statistics, but which, in some respects, is more successful than Tisza's (*4*) theory in explaining the properties of He II. Since Landau's theory makes no distinction between He^3 and He^4, it seems desirable to remove the last vestige of doubt about a superfluid transition in He^3 by investigating the flow properties of the *pure* liquid below 1° K. It is surprising that no experimental evidence has yet been found for nuclear alignment in liquid He^3; additional information on this point can be obtained by extending the melting curve below 0.5° K and by measuring the specific heat and heat of vaporization of the liquid.

From the experimental comparison of the two isotopic liquids, He^3 and He^4, it would almost seem as though they were different elements, and it must be concluded that the statistical behavior of the atoms—Fermi-Dirac for He^3 and Bose-Einstein for He^4—does indeed affect the macroscopic behavior.

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News and Notes

Scientists in the News

Lowell Besley, professor of forestry and dean of the Forestry School at the University of British Columbia, has been named executive director–forester of the American Forestry Association, effective July 1.

Robert W. Cairns, assistant director of research for the Hercules Powder Company, has been named vice-chairman of the Department of Defense Research and Development Board. He has been associated with the board since 1949 as a member of a panel of the Committee on Ordnance.

Hans T. Clarke, professor of biochemistry at the College of Physicians and Surgeons, Columbia University, gave the first A. J. Goldforb annual lecture, entitled "Fifty Years of Progress in Experimental Biology." The series of public lectures was endowed by former students and associates in honor of Dr. Goldforb, professor emeritus of biology, City College, New York.

Robert L. Cushing has been named director of the Pineapple Research Institute of Hawaii. He has been assistant director since 1951, and acting director since June 1952.

A scroll of appreciation was presented to **William Dameshek** for his teaching in hematology and his inspiring leadership over the past 25 years, by former and present associates on the occasion of the Advanced Course in Hematology at New England Center Hospital, Boston.

William von E. Doering, Yale professor of chemistry, who helped to synthesize quinine, will receive the $1000 American Chemical Society Award in Pure Chemistry in Los Angeles on Mar. 16.

Hugo C. Duzan, William R. McCallum, and **Thomas R. Todd** have received the Highway Research Board Award, given annually for an outstanding technical paper. The selection was made for their paper "Recent Trends in Highway Bond Financing," presented at last year's annual meeting of the board, and published in the *Proceedings.*

Ben Fisher has resigned as assistant director of hematologic research, Michael Reese Hospital, Chicago, to accept the newly created position of clinical pathologist at Wayne County General Hospital, Eloise, Mich.

George Gibson has been named acting chairman of the Chemistry Department at Illinois Institute of Technology during a nine-month leave of absence granted to **Martin Kilpatrick,** chairman.

Rolf Gran-Olsson, of the Norwegian Institute of Technology in Trondheim, will be visiting professor at Brown University in the Graduate Division of Applied Mathematics for the spring semester. He will teach courses in advanced elasticity and methods of technical mechanics.

Grayson L. Kirk, vice president and provost of Columbia University, has been named to succeed **Dwight D. Eisenhower** as president of the university. General Eisenhower became president-emeritus and trustee-emeritus, effective Jan. 19.

George A. Kolstad has been appointed chief of the Physics and Mathematics Branch in the AEC's Division of Research. Dr. Kolstad has been a physicist with the AEC in Washington since 1950.

Cheng Chun Lee has joined Eli Lilly and Company as a pharmacologist in the Toxicology Department. Dr. Lee, a native of Youngchow, Kiangsoo, China, received his Ph.D. from Michigan State College last year.

William S. Lohr, head of the Department of Civil Engineering, **Paul B. Eaton,** head of the Department of Mechanical Engineering, and **Luther F. Witmer,** of the Department of Metallurgical Engineering, will retire from the faculty of Lafayette College in June, each having served more than 30 years.

Charles H. Mann has been appointed medical director of Bristol Laboratories Inc. For the past three years he has served as medical director for the Heyden Chemical Corp.

Georg Masing, of the Institut für Allgemeine Metallkunde, Universitat Göttingen, has received the Institute of Metals (Platinum) Medal for 1953, for

contributions in the field of metallography. The institute's Rosenhain Medal for 1953 was awarded to **Charles Eric Ransley,** of the Research Laboratories, British Aluminium Co., Ltd., for experimental and theoretical work on gas-metal equilibria.

Harold S. Mitchell has been elected assistant vice president of Swift & Co. Mr. Mitchell, who has been with Swift for 40 years, will be succeeded by **Herbert E. Robinson** as director of laboratories.

Rufus Oldenburger, chief mathematician of the Woodward Governor Company, recently gave a series of lectures at the University of Paris on mathematical engineering analysis.

Jay F. W. Pearson, formerly executive vice president, has been appointed president of the University of Miami, succeeding the late **Bowman F. Ashe.** Dr. Pearson joined the university's Department of Zoology in 1926 and helped to create teaching and research interest in marine biology in the Miami area.

Sharat K. Roy, chief curator of geology at Chicago Natural History Museum, left recently for several weeks' study of the now-dormant volcano, Paricutin, in Michoacan, Mexico.

Calvin E. Schildknecht has joined the faculty of Stevens Institute of Technology, as an associate professor in the Chemistry Department, where, in addition to undergraduate courses, he will teach a special graduate course in plastics.

Richard M. Thomas, assistant professor of veterinary science at the University of Wyoming since 1949, has left for Palmer, Alaska, to assume the post of chief livestock sanitary official for the territory.

Eugene J. Thompson, former associate medical director of Winthrop-Stearns, has been appointed clinical director in the New Product Department of Vick Chemical Company. Dr. Thompson will devote half his time to Vicks and half to private practice and outside research.

V. A. Tiedjens, director of research, "Na-Churs" Plant Food Company, Marion, Ohio, has been awarded the Thomas Roland Medal by the Massachusetts Horticultural Society, for leadership in all phases of vegetable culture.

Kenneth C. Vincent has been appointed supervisor of extraction metallurgy at Armour Research Foundation of Illinois Institute of Technology. Dr. Vincent was formerly chief metallurgist for the Baroid Sales Division, National Lead Co., Houston, Tex.

Heinrich Waelsch, of the New York State Psychiatric Institute, received the 1953 Carl Neuberg Medal given by the American Society of European Chemists. Dr. Waelsch has done pioneering work on the biochemistry of the nervous system.

Harry F. Weaver has been promoted from assistant chief to chief of the Coal-Mine Inspection Branch, Health and Safety Division, Bureau of Mines.

Education

Bowman Gray School of Medicine of Wake Forest College and the **North Carolina Baptist Hospital** have established a medical foundation for the promotion of education, service, and research at the Winston-Salem Medical Center. Funds came through contributions from the professional staff of the school and hospital and friends of both institutions.

University of Illinois College of Medicine has promoted Craig D. Butler to professor of pediatrics, and Benjamin M. Gasul and C. J. Harrison to clinical associate professors.

New York University will create an Institute of Mathematical Sciences, of which David D. Henry will be administrative director and Richard Courant scientific director. The institute will consist of three divisions: Mathematics and Mechanics, Mathematics Research, and Computing Services—with a staff of about 120. An annual budget of $1,000,000 will be allocated to the work of the new program.

Oak Ridge Institute of Nuclear Studies will offer its first advanced course in the industrial uses of radioisotopes (Apr. 20–May 1), an advanced course in autoradiography (June 15–26), and three basic radioisotope techniques courses (four weeks each, beginning June 8, July 6, and Aug. 10). In addition there will be a symposium on "Management Problems in the Industrial Application of Radioisotopes," Apr. 30–May 1. Full information may be obtained from the Special Training Division of the institute, P. O. Box 117, Oak Ridge, Tenn.

The **Social Science Research Council Summer Institute in Mathematics** will be held at Dartmouth College, June 22–Aug. 14. It will be supported by a grant from the Behavioral Sciences Division of the Ford Foundation. William G. Madow, Robert M. Thrall, Robert R. Bush, and Howard Raiffa will be members of the teaching staff. Application blanks (returnable by *Feb. 9*) and full information may be obtained from the council, 726 Jackson Pl., N. W., Washington 6, D. C.

Yale University has entered into an agreement with the **University of Hawaii** and the **Bernice P. Bishop Museum,** Honolulu, for cooperative research in the Pacific area. The Carnegie Corporation of New York has made a grant of $200,000 in support of the program. The two principal lines of investigation will include field studies by anthropologists, linguists, and archaeologists to determine the spread of native peoples and cultures, and by anthropologists, sociologists, psychologists, and geographers to appraise the impact of Western civilization on the natives. The two universities will establish visiting lectureships, and a $4000 annual research fellowship will be offered by all three institutions. Direction will be under an executive committee composed of Paul Bachman, Alexander Spoehr, George P. Murdock, Harold J. Coolidge, and Leonard Mason.

Grants and Fellowships

Central Scientific Company, 1700 Irving Park Rd., Chicago 13, Ill., will award two scholarships for graduate study in 1953–54 to students majoring in the physical sciences and engineering. Stipends will range from $1000 to $1500, and applications must be made not later than *Apr. 15* to the Scholarship Committee.

The **Grass Trust for Research in Neurophysiology** will provide up to two fellowships for work at the Marine Biological Laboratory at Woods Hole, Mass., this summer. They will carry stipends of $500–$1000, or two candidates may apply jointly to work together, with stipends of $500 each. Letters of application or requests for information should be sent to Robert S. Morison, Room 5500, 49 W. 49th St., New York 20, before *Mar. 1.*

Ten fellowships will be awarded by the **University of Illinois** in the Colleges of Medicine, Dentistry, and Pharmacy. Stipends range from $1800 to $2400, and applicants need not have completed clinical internships. Applications must be filed by *Mar. 15* with Milan Novak. University of Illinois, 808 S. Wood St., Chicago 12, Ill.

Deadline for entries in the competition for the **Albert Lasker Awards for Medical Journalism** is *Feb. 16.* All newspapermen and magazine writers who have written medical or health articles during 1952 are eligible and may obtain entry blanks and other information from the Nieman Foundation for Journalism, 44 Holyoke House, Cambridge 38, Mass.

The **C. K. Leith Fellowship in Geology,** carrying a stipend of $1200, is available at the University of Wisconsin for a graduate student whose major interest is in the field of mineral economics and resources. For full information and application forms, which must be filed by *Mar. 22,* write to the chairman of the Department of Geology.

New York University Graduate Division of Public Service offers fellowships, with stipends up to $2400, scholarships covering full or part tuition, and assistantships with stipends of $1200 plus tuition. All candidates must have completed work for the bachelor's degree by June 1953 and applications must be filed by *Mar. 16.* William J. Ronan is director of the division.

A **Scripps Fellowship** (carrying a stipend of $2500 for ten months) will be available in June for research at the Zoological Society of San Diego on a problem that will make use of available material and be of benefit to the zoo. Applications and inquiries should be addressed to Glen G. Crosbie, Box 551, San Diego 12, Calif.

A **Waksman-Merck Postdoctoral Fellowship in the Natural Sciences** has been established at Rutgers University by Merck & Co., in honor of Selman A. Waksman. The award is $4000 for one calendar year, beginning July 1, and deadline for receipt of applications is *Mar. 1.*

In the Laboratories

The **University of Arizona** will establish a carbon 14 age determination laboratory under the direction of Emil W. Haury. Technical supervisor will be Edward N. Wise. The research will be supported by a $6000 grant from Research Corporation, of New York.

Armour Research Foundation has appointed S. Frederick Magis, steel technologist, to one of the Point IV projects of the International Division, with headquarters in Karachi. James D. Long, agricultural engineer, has been assigned to a Point IV project in India, and Howard D. Goodman, automotive technologist is working in Pakistan to standardize bus and truck designs, set up mass-production systems, and train operators to teach handling, service, and maintenance. Joshua N. Goldberg has been appointed an associate physicist at the foundation.

Carborundum Metals Company, Inc., a new subsidiary of Carborundum Company, is building a $2,500,000 plant to produce zirconium and hafnium at Akron, N. Y. Production will be under a five-year AEC contract.

New chemical research laboratories for the **Funk Foundation for Medical Research, Inc.,** were dedicated recently in New York City. The laboratories are named for Casimir Funk, who will continue to direct studies on cancer, diabetes, asthma, arthritis, poliomyelitis, and mental ailments.

A **General Research Organization** has been established for Olin Industries, Inc. It will conduct basic research and work with all eight Olin manufacturing divisions on long-range and specialized problems. Laboratories have been established at New Haven, Conn., and East Alton, Ill. The following research heads have been appointed: Herman Bruson, organic chemical; Melvin M. Johnson, Jr., armament; Hibben Ziesing, petrochemical; Robert L. Womer, new products; and Oscar J. Swenson, chemical engineering.

National Research Corporation has appointed Milo P. Hnilicka, Jr., to the Chemistry Department, and George A. Sofer to the Applied Physics Department. Dr. Sofer has been a research assistant at MIT, and Dr. Hnilicka, who was in charge of development at the Czechoslovakian Motor Fuel Works at the time of the Communist *coup d'état* in 1948, later escaping with his family to the U. S. Zone, was brought to the U. S. under the sponsorship of Hydrocarbon Research, Inc., in 1949. He has most recently been project development engineer for Carthage Hydrocol, Inc., at its Brownsville, Tex., plant, and will work at National Research on low-cost reduction of metallic titanium, a program jointly sponsored with **Monsanto Chemical Company.**

Sterling-Winthrop Research Institute has appointed Frederick Coulston head of the Pathology Section. Since 1948 Dr. Coulston had been in charge of the Histopathology Laboratory of the Institute of Medical Research of Christ Hospital, Cincinnati.

Meetings and Elections

Anyone living in the vicinity of Springfield, Mass., who would like to attend meetings of the **AAAS Springfield Chapter,** should get in touch with P. H. Cinis, 73 Melha Ave., Springfield.

A **Conference on Nutritional Factors and Liver Diseases** will be held under the auspices of the Section of Biology of the New York Academy of Sciences at the Barbizon-Plaza Hotel, Feb. 13–14. Session chairmen will be Klaus Schwarz, Charles S. Davidson, J. F. Brock, Floyd S. Daft, and Charles H. Best. Attendance is limited to those invited to participate and to academy members.

The **Institute of Radio Engineers** has reappointed Haraden Pratt secretary, W. R. G. Baker treasurer, and Alfred N. Goldsmith editor. Appointed directors for 1953 were Ralph D. Bennett, William R. Hewlett, and Arthur V. Loughren.

A **Midwestern Conference on Fluid Mechanics** will be held at the University of Minnesota Mar. 23–25. Thomas Baron, G. R. Eber, J. O. Hirschfelder, Arnold M. Kuethe, Franklin K. Moore, and Vito A. Vanoni are among the invited speakers, and in addition about 35 contributed papers will be presented. R. Hermann, of the Department of Aeronautical Engineering, University of Minnesota, is general chairman, and E. Silberman, of St. Anthony Falls Hydraulics Laboratory, Minneapolis, is program chairman. The conference is sponsored by the American Physical Society, Fluid Dynamics Division, and local sections of the American Institute of Chemical Engineers, American Society of Civil Engineers, American Society of Heating and Ventilating Engineers, American Society of Mechanical Engineers, and the Institute of Aeronautical Sciences.

A **Symposium on Air Pollution and its Control** will be held at Wagner College, Mar. 7, under the auspices of the Department of Bacteriology and Public Health and the Borough President's Committee for Air Pollution Abatement. Natale Colosi is chairman of the program, to which all interested individuals are invited.

Miscellaneous

The **American Museum of Natural History** and the **R/W Maintenance Corporation,** of Buffalo, N. Y., have released a 23-minute colored sound motion picture entitled "Chemical Brush Control of Right-of-Ways. A Scientific Program of Vegetation Management." The film demonstrates the botanical system of brush control developed by Frank E. Egler, of the museum staff, and may be obtained on loan from either organization for commercial or scientific showings.

The **British Columbia Research Council** at the University of British Columbia has made the following new appointments: Chemistry Division: H. Friedeberg, W. F. Gruber, H. G. Khorana, J. F. Smith, and J. D. H. Strickland; Metallurgy Division: I. D. G. Berwick, J. G. Parr, and J. E. Srawley.

The **Department of Scientific and Industrial Research** has issued reports on *Fire Research 1951* (50¢) and *Water Pollution Research 1951* (65¢). The former analyzes the cost of recent large fires in the United Kingdom and presents the results of research on special fire hazards. The latter gives special attention to the treatment of sewage and waste waters and reports at length on a detailed survey of the Thames estuary. Both pamphlets can be purchased from British Information Services at Rockefeller Center, New York.

Recent visitors from Tokyo at the **National Bureau of Standards** included Yoshitoro Miyoshi, Tokyo Shibaura Electric Co.; Makoto Kizawa, Tanashi-machi, Kitatama-gun; Ietsune Tsubokawa, Geographical Survey Institute; Hiroshi Suzukawa, Canon Camera Co.; Sakae Fujiki, Radio Regulatory Bureau, Ministry of Postal Services; and Juichi Osawa and Yujiro Degawa, of the Nippon Electric Co. Other Japanese visitors included Yoshia Nagamori, Fujikoshi Kosai Kogyo Co., Toyama; Takezo Sato and Shichihei Asakama, Tokyo Shibaura Electric Co., Yokohama; Tokunosuke Watanabe, Osaka University; Tatsuo Hayashi, Radio Precision Corp., and Television Society of Japan, Osaka. Visitors from other countries were Carlos de Miranda, Serviço Especial de Saude Publica, Rio de Janeiro; John A. Cole, Mechanical Engineering Research Organization, Glasgow; F. B. Shorland, DSIR, Wellington, N. Z.; Chao-Tung Chen, National Taiwan University, Formosa; Johannes Steyn, South African Council for Scientific and Industrial Research; and René Eyhéralde, Housing Research Center of the Pan-American Union, Bogotá.

Proceedings of the First International Symposium on Bacteriophage, held at Royaumont, France, in July 1952, became available in January, as Vol. 84 of the *Annales de l'Institut Pasteur.* A limited number of this special issue, edited by André Lwoff, is available from the Institut, 25 rue du Dr. Roux, Paris XV, at 1675 French fr. or $4.50.

Chemicals wanted by the **Registry of Rare Chemicals,** 35 W. 33rd St., Chicago 16, Ill., include: cesium hydride; molybdenum oxydichloride; rubidium sulfide; sodium fluotitanate; niobium pentafluoride; methionic acid; perfluorodecanoic acid; pentacosanic acid; 2-formyl-3-carboxyl pyridine; 2,3,4-trichlorophenol; diphenyl-3,3′-dicarboxylic acid; oxime-5-carboxylic acid; 2-mercaptoimidazole; alloocimene; phenazine methochloride; adamantane; camphoquinone; glycyl-L-phenylalaninamide; ergothioneine; and furocoumarin.

U. S. Rubber Company has appointed John McGavack technical director of the Plantation Division, succeeding E. M. McColm, who has been transferred to the General Laboratories in Passaic, N. J.

Technical Papers

Selective Reduction of the Unsaturated Compounds: Deuterization of the Raney Nickel Catalysts

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Experience with deuteration and hydrogenation of the unsaturated compounds (*1, 2*) has indicated that both processes are of the same nature and follow the same pattern of reactions. Apparently the catalysts reduce the differences in reaction characteristics of the two isotopes. As a result of these observations, it was deemed desirable to prepare deuterized Raney nickel for deuteration of the unsaturated compounds. In the present investigation, only those hydrogenation catalysts which are prepared free of alkali were used. The traditional catalysts, W-1 (*3*), W-2 (*4*), and W-3 (*5*) satisfy this requirement. Of these three, W-1 is the least active and therefore can be used for reduction of unsaturation without reduction of the ester group, but W-2 and W-3 are equally active in both cases. For these reasons, W-1 was used for reducing methyl stearolate to di-deutero-oleate and W-2 and W-3 were allowed to reduce 9, octadecyne to 9, 10-di-deutero-octadecene in order to determine the extent of deuteration. However, these catalysts may be employed for all types of deuteration, in the same manner as for hydrogenation (*3–7*).

For deuterization, the catalysts were stored in purified dioxane (*8*). Twenty-five g of Raney nickel (still wet with dioxane) were twice washed with 25 ml portions of dioxane by centrifugation. The catalyst was then transferred to a 250-cc modified reaction vessel (Fig. 1) of the Joshel hydrogenator (*9*) by washing it into the vessel with 50 ml of dioxane. Stopcock *a* just above the reaction vessel was closed, the main system evacuated, flushed with D_2 gas and then the reservoir of the apparatus was filled with 300 ml D_2 gas. Stopcocks *b* and *c* were opened and oxygen-free nitrogen was allowed to flush the reaction vessel. On closing stopcock *b* a sufficient vacuum was applied through stopcock *c* by means of a water pump to draw out the nitrogen gas with a minimum vaporization of the dioxane. Stopcock *c* was then closed and *a* was opened. The reaction vessel was filled with D_2 gas under a slight pressure, as indicated by difference in mercury level of 2.5 cm in the manometer of the hydrogenator. Stopcock *a* was closed, and the catalyst was agitated in the presence of D_2 gas for 3 hr. The

FIG. 1. Reaction vessel for deuterization.

reaction vessel was again flushed with oxygen free nitrogen, and the above process was repeated five times. Then the vessel was again flushed, filled with fresh D_2 gas, and the catalyst was agitated for 24 hr. Nickel prepared in this manner was stored in brown bottles, filled with dioxane through which D_2 had been bubbled and to which a few ml of D_2O had been added. These stored materials should be completely protected from oxygen, ordinary water, halogen, and sulfur compounds. Since W-2 and W-3 catalysts hold more hydrogen (*7*), it was necessary to agitate the catalyst for 3 hr in each of seven changes of D_2 before the final 24-hr exposure. The deuterium analyses of the deutero compounds prepared by the different catalysts were very satisfactory, being in the range of 95–98 atoms per cent.

Future plans include investigation to determine the best ways to deuterize the alkaline catalysts, W-4 (*5, 10*), W-5 (*11*), and W-7 (*11*), as well as the alkali-free catalyst W-6 (*11*), which contains the greatest amount of hydrogen. Deuterium content of the gases held by the individual catalysts will be investigated by mass spectrographic analysis. The preparation of these deuterized catalysts will facilitate deuteration and deuterolysis of organic compounds that may be used as "tracers" in both the chemical and biological reactions.

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Manuscript received July 7, 1952.

[1] At present a research fellow at Hormel Institute, Austin, Minn.

[2] The author wishes to thank F. E. Deatherage and J. B. Brown, of Ohio State University, for their help during the progress of the work.

Serial Position Curves in Verbal Learning

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When a list of nonsense syllables is learned by a subject under conditions that require him to recall the following syllable as each one of the series is presented, it is found that the syllables in the middle of the list are learned more slowly than are those at the two ends, and that in general the initial syllables are learned more rapidly than are the final ones. When the results are plotted in terms of mean number of errors made at each serial position during learning, the graph has the form shown in Fig. 1.

Of the various theories proposed in explanation of the relatively slow rate at which the middle of the series is learned, that of Lepley (*1*) and Hull (*2*) has been the most ingenious and perhaps the best substantiated. The Lepley-Hull theory is that the bow-shaped serial position curve results from the large number of inhibitory processes present in the middle of a series of responses. It is known that during learning each syllable becomes associated not only with adjacent but also with remote syllables, so that both near and remote excitatory tendencies are set up. Progress toward mastery of the list involves a strengthening of the near excitatory tendencies and the weakening (or control) of the remote ones to the point where, when a given syllable is presented, the subject will report the next following syllable and not one farther along in the list, or none at all. A simple diagram can be constructed to show that remote excitatory tendencies pile up in the middle of the list. Proceeding from this point, an analogy is drawn between serial learning and conditioning. It is held that each succeeding syllable in the series becomes conditioned to the traces of preceding syllables so that remote associations are viewed essentially as trace-conditioned responses. Final mastery is attained as a result both of the building up of internal inhibitions of the trace responses and of the strengthening of near excitatory tendencies. Inasmuch as the trace response tendencies are most numerous in the middle of the series, the inhibitory tendencies must be concentrated in the same location, to the relative neglect of the two ends. Many observations, particularly on the spontaneous recovery of extinguished responses, support the view that inhibitory tendencies dissipate more rapidly with the lapse of time than do excitatory tendencies. One can therefore make experimental tests of the effects of various manipulations of the time variable upon the serial position curve, looking for results that may or may not support the inhibition theory.

The most significant data on the serial position curve with respect to this theory come from experiments on massed vs. distributed practice and on changes in the rate of presentation of the syllables. In massed learning, practice periods follow one another with little or no rest between the periods, whereas in distributed learning there are rest periods of varying lengths at the close of each practice period. Within limits, distributed practice results in quicker learning than does massed practice. The inhibition theory predicts that the lapse of time involved in the rest periods of distributed practice will result in a relative loss of inhibitory tendencies and that, therefore, the serial position curve for distributed learning when compared with the massed learning curve will show a decrease in errors at each position but with the largest decrease in the middle portions of the curve, where the inhibitory effects have been greatest. Similar predictions are made for the effects of varying the rate at which syllables are presented, since, with a slow rate, inhibitory tendencies may be expected to dissipate more rapidly than with a faster rate of presentation.

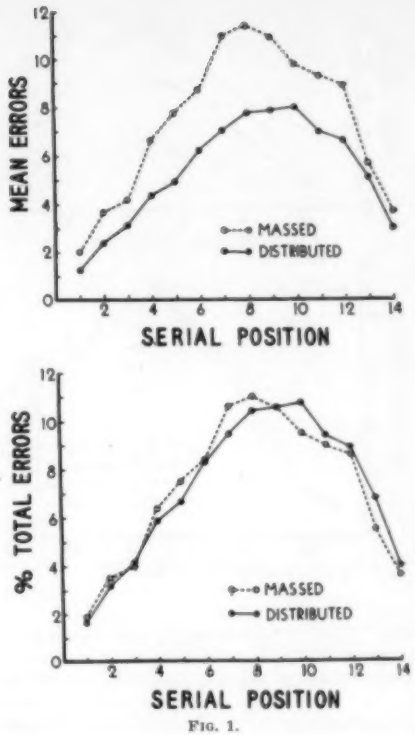

FIG. 1.

Patten (*3*) and Hovland (*4, 5*) have conducted experiments of the above type. The upper half of Fig. 1 shows the essential results secured by Hovland (one of many experiments) when subjects learned a list of 14 syllables presented at a rate of 1 syllable each 2 sec. In the distributed practice series, there was a rest interval of 2 min 6 sec between successive presentations of the list, whereas in the massed practice series the rest period was only 6 sec. The decrease

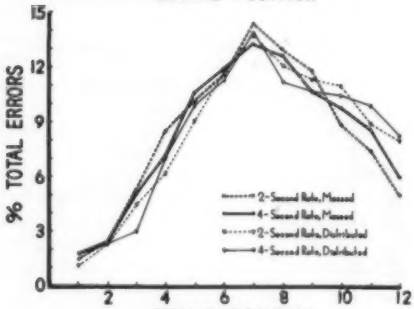

FIG. 2.

in mean errors brought about by distributed practice shows up at all serial positions, but it is greatest in the middle of the series, as predicted by the inhibition theory. In another experiment, Hovland compared the serial position curves for the learning of 12-syllable lists under conditions of massed vs. distributed practice, using 2-sec and 4-sec rates of presentation per syllable. The mean number of errors per serial position under these various conditions is shown in the upper half of Fig. 2. Again there is evident a marked decrease in mean errors when distributed practice is compared with massed practice, with the greatest decrease in the central portion of the curve. The change from a 2-sec to a 4-sec rate of presentation has little effect under conditions of distributed practice, but a significant effect in massed practice.

The curves in the lower halves of Figs. 1 and 2 show the serial position curves of the upper halves of the figures plotted in percentages, with the mean errors at each position expressed as a percentage of the total mean errors made under a given practice condition. (Since we did not have access to Hovland's original data, the values are computed either from his curves or from his tables. In either case any errors in the calculations would be small.) The striking feature of the percentage plots is that there is essentially no difference in the curves for the different conditions of learning. This is also true for the percentage plots we have made of the data in eight other investigations by various authors. In all cases there was practically complete identity of the percentage serial position curves for the greater and lesser conditions of efficiency within a given experiment, with a rare maximum difference of 3.5% for a given serial position.

The reason for plotting percentage mean error curves is as follows, stated in terms of the experiment on massed vs. distributed practice: Since distributed practice is more efficient than massed practice, fewer errors are made during learning under the former than under the latter condition. Graphs of mean errors per syllable position, therefore, must give two curves which differ in their ordinate values much as is the case in Fig. 1, irrespective of the explanatory theory being investigated. When the absolute mean error curves are equated for area by plotting them in percentage terms, any essential differences in form are observable. The percentage curves of Figs. 1 and 2 show that the several serial positions have the same order of relative difficulty under the more and the less efficient methods of learning. From the standpoint of the Lepley-Hull inhibition theory, the percentage curves are more significant than the mean error curves, since they show that the reduction of errors brought about by the introduction of elapsed time intervals occurs throughout the series in proportion to the total errors made and in the same overall manner as where no elapsed time is introduced. This does not prove the inhibition theory, but it is consistent with it.

In a further attempt to throw light on the serial position curve and on the relevancy of the inhibition theory, we have conducted an experiment on the serial learning of 14 nonsense syllables vs. 14 familiar names (an initial cue item was added to each list) by the conventional anticipation method counterbalancing the two series. In order to balance out any unevenness in difficulty of the specific items, each subject entered the list at a different point so that, for example, the syllable or name in serial positions 3 and 4 for one subject would be in positions 4 and 5 for another subject. The items were presented at a 2-sec rate, with the intertrial interval set at 8 sec. Learning was completed in one session, massed practice, to a

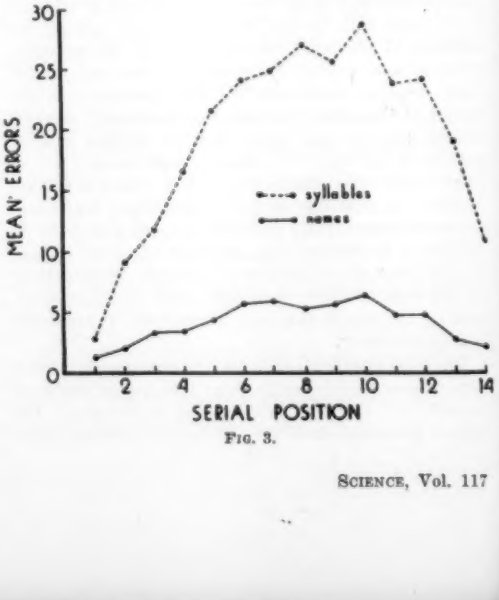

FIG. 3.

criterion of one correct anticipation of each syllable in the course of one trial. The association values of the syllables were from 0 to 3% according to Hull's calibration (*6*). The names were the family names of the 16 graduate students who served as subjects and who, at this time, were well acquainted with each other. The mean number of trials required for learning the syllables was 39 and for learning the names, 11.

Fig. 3 gives the serial position curves for syllables and names plotted in terms of mean errors, and Fig. 4 replots the same data in terms of the percentage of total errors made at each serial position. Again it is to be noted that (1) the curves are the familiar bow-shaped ones current in the literature, (2) the greatest gain in efficiency occurs in the middle of the series or just past the middle, and (3) the percentage plots are essentially identical. Items 2 and 3 above were brought about by the use of familiar names vs. nonsense materials as the material to be learned and not by the introduction of elapsed time, which might allow for a decrease of inhibitory tendencies as predicted by the Lepley-Hull theory.

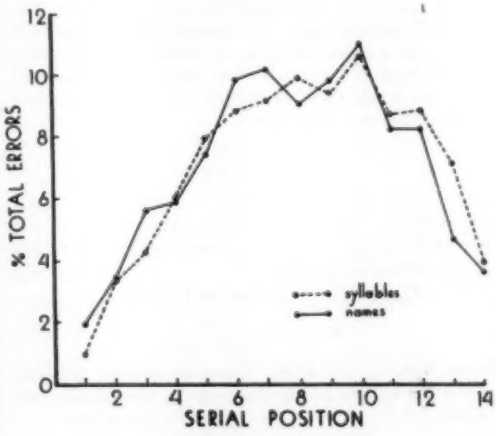

FIG. 4.

The 16 subjects of the above experiment were classified as quick or slow learners on the basis of being in the upper or lower half of the group in total errors made during learning. The upper half of Fig. 5 presents the serial position curves for these two groups in learning familiar names as described above, and the lower half gives the curves on a percentage basis. Similar curves were found for quick vs. slow learners in the nonsense syllable learning of these 16 subjects, as well as in the experiment (not here reported) with 48 subjects in the learning of familiar and unfamiliar nonsense syllables.

The general conclusions from the above experiments and analyses are as follows: (1) Any experimental condition which increases the efficiency of serial verbal learning and which thereby decreases the total number

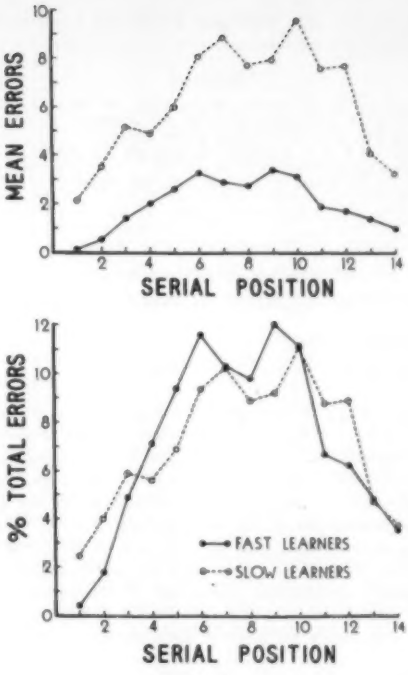

FIG. 5.

of errors made will result in a serial position curve of mean errors which lies below the curve for a less efficient method of learning. (2) The reduction in mean errors per serial position, although greatest in the middle or just past the middle of the series, will be closely proportional at each position to the total number of errors made. It is in no sense surprising that, when one changes from a less to a more efficient method of learning, the greatest reduction of errors will occur in the central serial positions. This is not a confirmation of the inhibition theory but merely an evidence of the fact that significant gains in efficiency can only occur where serious errors have been made—namely, in the central part of the series. It is surprising, however, that the gains under a more efficient learning method should be as proportionately distributed as the percentage curves indicate.

The theoretical problem still remains of explaining why the serial position curves for verbal learning are bow-shaped. We can offer no solution ourselves, although we believe that a multiple- rather than a single-factor theory will finally be indicated. The Lepley-Hull inhibition theory is plausible only under the conditions discussed above, where lapses of time were introduced into the learning process. In order to rank as an adequate general theory it would need to be shown that *any* condition which increased the efficiency of serial verbal learning (including meaning, familiarity, and quick learning ability) decreased pro-

portionately the inhibitory tendencies postulated in connection with the various serial positions.

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Manuscript received July 25, 1952.

An Electromagnetokinetic Phenomenon Involving Migration of Neutral Particles[1]

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Electrically neutral particles migrate in a magnetic field traversed by an electric current. The migration is perpendicular to the current and to the homogeneous magnetic field that is maintained at right angles to the current. If the electrical conductivity of the particles exceeds that of the surrounding conductive fluid, the particles migrate in the direction of the force exerted in the magnetic field upon the current. Particles of lesser conductivity than that of the surrounding fluid migrate in the opposite direction, whereas particles experience no force if their electric conductivity is equal to that of their environment.

The force of gravity, as well as the force of buoyancy exerted upon a suspended body, can be neutralized. For instance, an air bubble will not rise in acidulated water placed in a horizontal magnetic field of 10,000 oersteds traversed by a perpendicular horizontal current of 1 amp/cm^2.

Explanation of the effect. This effect is due to the establishment of a pressure gradient (analogous to the hydrostatic pressure gradient in the gravitational field) in an enclosed conductive fluid traversed by a homogeneous electric current and a homogeneous magnetic field perpendicular to that current. Each volume element of the fluid experiences a force perpendicular to the magnetic field and to the current of the magnitude

$$dF = (\mu H j)\,dV, \tag{1}$$

where μ is the magnetic permeability of the fluid, H the magnetic field strength, j the current density, and dV the fluid volume element. The force upon a finite volume V of arbitrary shape is

$$F = \int (\mu H j)\,dV = (\mu H j)V. \tag{2}$$

The expression (μHj) corresponds to the specific weight in the hydrostatic analogy, and the force F to the weight of the volume ("electromagnetic weight," EMW). Since the fluid element V remains at rest despite the action of the force F, we conclude that an equal and opposite force is exerted upon it by the surrounding fluid. This force is comparable with the buoyancy in our hydrostatic analogy, being a consequence of the pressure field set up in the fluid by the interaction of the current with the magnetic field. We shall refer to this force as "electromagnetic buoyancy" (EMB). If the volume element V is occupied by a substance the electrical conductivity of which differs from that of the surrounding fluid, $EMW \neq EMB$ and the immersed body experiences an unbalanced force. In this case, however, a streaming of the fluid is engendered around the immersed object so that the hydrostatic forces alone do not suffice for a complete description of the effect. The following treatment is an approximation in which hydrodynamic effects are neglected.

Estimate of the force upon a sphere. The EMW of a sphere of conductivity σ_1, immersed in a fluid of conductivity σ_2 of infinite extent traversed by a homogeneous magnetic field and a perpendicular homogeneous electric current, can be estimated easily as follows: Maxwell (*Treatise on Electricity and Magnetism*, par. 313) has shown how to compute the electric field inside a sphere of conductivity σ_1 submerged in a fluid of conductivity σ_2 in which a homogeneous electric field of intensity E_2 is maintained. The electric field inside the sphere (E_1) is homogeneous and is given by the expression

$$E_1 = E_2 \frac{3\sigma_2}{2\sigma_2 + \sigma_1}. \tag{3}$$

The external field in the vicinity of the sphere is not homogeneous. Eq. (3) is valid strictly only if the sphere is negligibly small as compared to the extent of the surrounding fluid.

Eq. (3) can also be written as follows:

$$E_1\sigma_1 = E_2\sigma_2 \left(\frac{3\sigma_1}{2\sigma_2 + \sigma_1}\right). \tag{3a}$$

Since $E_1\sigma_1 = j_1$ and $E_2\sigma_2 = j_2$ are the current densities inside the sphere and in the medium, respectively, we obtain for the current density inside the sphere

$$j_1 = j_2 \left(\frac{3\sigma_1}{2\sigma_2 + \sigma}\right). \tag{4}$$

According to Eq. (2) the EMW of the sphere is

$$F' = \mu H j_1 V = \mu H j_2 V \left(\frac{3\sigma_1}{2\sigma_2 + \sigma_1}\right). \tag{5}$$

If we assume for the EMB exerted upon a submerged volume V the force (F'') given by Eq. (2) we obtain

$$F'' = \mu H j_2 V. \tag{2a}$$

Thus, we can write:

$$F' = F'' \left(\frac{3\sigma_1}{2\sigma_2 + \sigma_1}\right). \tag{5a}$$

The resultant force upon the sphere is

$$F = F' - F'' = F'' \left(\frac{3\sigma_1}{2\sigma_2 + \sigma_1} - 1\right)$$
$$= \mu H j_2 V \left[\frac{2(\sigma_1 - \sigma_2)}{2\sigma_2 + \sigma_1}\right]. \tag{6}$$

[1] This work has been supported by a grant from the Abbott Memorial Fund of the University of Chicago.

[2] The author wishes to thank E. M. Gelbard for many stimulating discussions and G. E. Backus for a critical reading of the manuscript.

In general, assuming $\sigma_1 = n\sigma_2$, we can write:

$$F = \mu H j_2 V \left[\frac{2(n\sigma_2 - \sigma_2)}{2\sigma_2 + n\sigma_2}\right] = \left(\frac{n-1}{n+2}\right) 2\mu H j_2 V. \quad (7)$$

From this equation we can determine the resultant force for various special cases. For instance: For a *dielectric sphere* $\sigma_1 = 0$, so that $n = \sigma_1/\sigma_2$ vanishes in Eq. (7). Thus, we obtain

$$F = -\mu H j_2 V \quad (8)$$

as the expression for the magnitude and direction of the electromagnetic buoyancy. For a *metallic sphere* in an electrolytic fluid we can, in most cases, consider σ_2 negligible as compared to σ_1, so that $n = \frac{\sigma_1}{\sigma_2} \gg 1$. In this instance we obtain the approximation

$$F = 2\mu H j_2 V. \quad (9)$$

In the case of living cells, the conductivity commonly differs but little from that of the environment; we can then assume in Eq. (6) $\sigma_1 \simeq \sigma_2 = \sigma$, and $\Delta\sigma = \sigma_2 - \sigma_1 \ll \sigma$. We thus obtain the following approximation:

$$F = \left(\frac{\Delta\sigma}{\partial\sigma}\right) 2\mu H j_2 V. \quad (10)$$

The preceding calculations do not represent an exhaustive treatment but merely an approximation which, in some cases, agrees quite closely with experimental data. A complete theory should take into account the following factors: distortion of the electric and magnetic fields caused by the inhomogeneities in σ and μ introduced by the immersed body; changes in the hydrostatic pressure distribution, as well as streaming of the liquid caused by these field distortions; and, finally, the effect of the magnetic field upon the current distribution and electrolyte concentration.

Experimental determination of the force exerted upon a sphere. Fig. 1 illustrates the agreement between the prediction (Eq. [8]) and experimental determination of the force exerted upon glass spheres. The spheres were suspended from a balance arm in a solution of copper sulfate, through which a horizontal current was passed ($j = 0.146$ amp/cm^2) at right angles to a horizontal magnetic field ($H = 1857$ oersteds). The straight line represents the predicted *EMB*. The circles indicate experimentally obtained points. The experimental values of the force agree with the predicted values within the limits of experimental error.

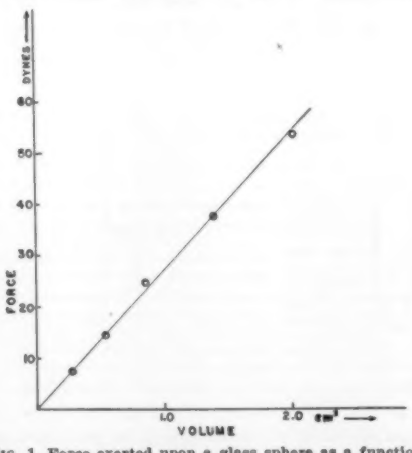

FIG. 1. Force exerted upon a glass sphere as a function of the volume of the sphere. The straight line represents predicted values; the circles indicate points determined experimentally.

FIG. 2. Refraction of electric current lines. Distribution of current density (*A*) for a sphere with conductivity equal to that of its environment, (*B*) for a sphere of lower conductivity, (*C*) for a sphere of higher conductivity. In all cases shown the current density inside the sphere is uniform. It is decreased in case (*B*) and increased in case (*C*) as compared to j outside the sphere.

The checking of Eq. (9) by suspending metallic spheres in an electrolytic solution is much more difficult. A copper sphere, for instance, suspended in a solution of $CuSO_4$, experiences a force in the predicted direction—namely, opposite to the force exerted upon a glass sphere. But the magnitude of the force does not remain constant. Rather, it drops to zero within a few seconds for a current density of 0.5 amp/cm^2. A sustained force can be obtained using a zinc sphere in an acidulated solution of $ZnCl_2$. The value found fluctuates, however, about 60% of the value predicted by Eq. (9). The results obtained with Cu and Zn may be due to an electrolytic "fatigue effect" of the following kind.[3] Fig. 2 shows the current distribution (*A*) in the case of a sphere with conductivity equal to that of the surroundings ($F = 0$), (*B*) for a sphere of lesser conductivity than the environment, and (*C*) for a sphere with conductivity exceeding that of the surrounding fluid. Electrochemical processes on the surface of the sphere (such as liberation of gas) which tend to change the current distribution from the one pictured in Fig. 2 *C* to that of Fig. 2 *A* would tend to diminish the force exerted upon the sphere. The fatigue effect would be greatest in the region of the highest current density.

Transport of neutral bodies. The migration of bodies suspended in a conductive fluid can be demonstrated quite effectively by suspending mustard seeds and whitefish eggs in a concentrated solution of sucrose containing a small amount of an electrolyte.[4] When

[3] Effects of electrolytic processes upon the current distribution in metallic bodies submerged in current-carrying electrolytes have been described by J. Stark (*Ann. Physik*, **66**, 245 [1898]). He found that polarization may cause a redistribution of currents entering the metallic body.

[4] In order to maintain the seeds and eggs in suspension, a density gradient was created by pouring a solution free of sucrose on top of the sucrose-electrolyte solution.

TABLE 1

Radius in cm	Terminal speed in cm/sec
10^{-4}	10^{-4}
10^{-3}	10^{-3}
10^{-2}	1
10^{-1}	10^{2}

the conductivity of the solution is less than that of the fish eggs, one can see the eggs and the seeds migrate in opposite directions with a speed of the order of magnitude of 1 cm/sec at a current density of 0.1 amp/cm² in a magnetic field of about 2000 oersteds. Their direction of migration can be reversed by reversing the electric current or the magnetic field. The direction of migration of the fish eggs coincides with the direction of the force exerted upon the current. The direction of this migration can be reversed by increasing the conductivity of the solution sufficiently.

Table 1 shows computed values of the velocity of migration of nonconductive spheres of different sizes in an aqueous electrolytic solution in a magnetic field of 5000 oersteds at a current density of 1 amp/cm². The figures were obtained by substituting the value of F given by Eq. (8) in Stokes' law,

$$F = 6\pi\eta R v. \tag{11}$$

We obtain

$$v = \frac{1}{45}\frac{Hj}{\eta}R^2 \tag{12}$$

for the terminal velocity of a sphere of radius R (j is measured in amp/cm², and in Table 1 η is assumed to be $= 10^{-2}$ poise).

The observation of the migration of microscopic particles is much more difficult than that of macroscopic ones. This is mainly due to the difficulty of obtaining a perfectly homogeneous magnetic field. A circulation that drags mostly the smallest particles along is engendered in the electrolytic cell if the magnetic field throughout it is not sufficiently homogeneous, or if the current density is not uniform. A simple, satisfactory cell for microscopic observation can be made by drilling a narrow channel into lucite and sealing it at both ends with screws, which serve as electrodes. Placing such a cell vertically in the gap of a magnetron magnet, one can easily observe and measure the speed of migration of commercially obtainable polystyrene spheres of the order of magnitude of 10^{-2} cm in diameter.

Effect of shape and orientation of suspended bodies. A rigorous calculation of the force exerted upon the submerged body would be difficult to carry out, except for a few special cases of favorable shape and orientation. A complicating factor is the evaluation of the effect of the electromagnetically engendered streaming of the fluid upon the immersed body. So far, the effects of shape and orientation have been investigated in a purely experimental fashion.

Fig. 3 shows how the current distribution in the case of a sphere of higher conductivity than its environment (shown in Fig. 2 *C*) is altered when the sphere is distorted into a prolate (Fig. 3 *A*) or an oblate spheroid (Fig. 3 *B*). In the former case the excess of the current density inside the body over its value in the surrounding fluid is larger than for a sphere (Fig. 2 *C*), whereas in the latter case it is smaller. This excess becomes vanishingly small for a disk the thickness of which is negligible as compared to its diameter (Fig. 3 *C*). In this case the refraction of the current lines can be disregarded except near the edges of the disk (not shown in the figure). Since the current density inside the disk is nearly the same as in the surrounding fluid, we expect the force to be vanishingly small. This is confirmed by experiment. The force upon a Zn disk of $R = 0.65$ cm and thickness $h = 0.23$ cm immersed in a solution of $ZnCl_2$ was found to be imperceptible when oriented as described above.[5] When the disk was rotated through

[5] The fact that the diameter of the disk was not small as compared to the diameter of the vessel containing the fluid is partly responsible for the smallness of the observed force.

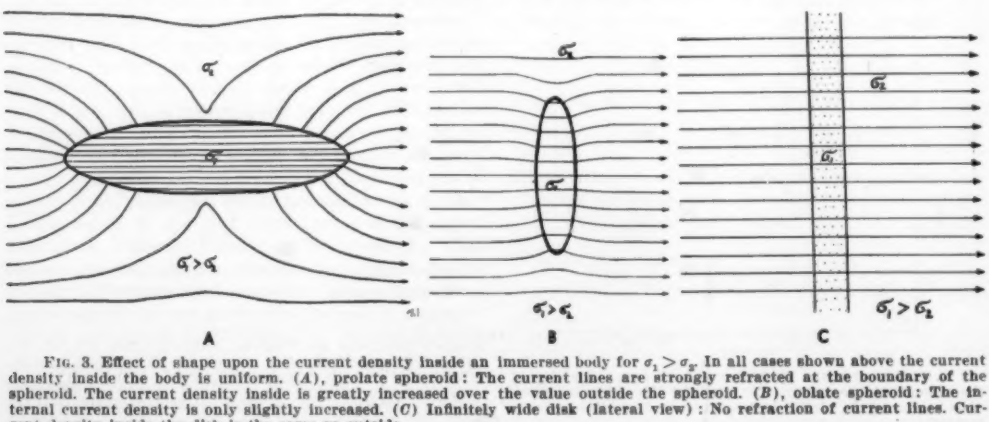

FIG. 3. Effect of shape upon the current density inside an immersed body for $\sigma' > \sigma''$. In all cases shown above the current density inside the body is uniform. (*A*), prolate spheroid: The current lines are strongly refracted at the boundary of the spheroid. The current density inside is greatly increased over the value outside the spheroid. (*B*), oblate spheroid: The internal current density is only slightly increased. (*C*) Infinitely wide disk (lateral view): No refraction of current lines. Current density inside the disk is the same as outside.

TABLE 2

Body	Diameter (cm)	Height (cm)	Orientation of cylinder axis	Force measured in dynes	Computed EMB in dynes
Bakelite disk	1.55	0.3			
			$\parallel H$ and $\perp j$	16.1 ± 1.0	15.5
			$\parallel j$ and $\perp H$	12.0 ± 1.0	15.5
Bakelite cylinder	0.53	2.12			
			$\parallel j$ and $\perp H$	13.3 ± 0.5	12.8
			$\perp H$ and $\perp j$	9.4 ± 0.5	12.8
			$\parallel H$ and $\perp j$	1.1 ± 0.5	12.8

90° so that the magnetic lines of force entered its circular faces at right angles, a force $F = 49.0$ dynes was exerted upon it. The force computed from Eq. (9) for a metal sphere of equal volume under the same conditions is 16.7 dynes. In the latter position the disk experiences a torque that tends to set its cylinder axis parallel to the current.

With an elongated Zn cylinder, with dimensions $L = 1.70$ cm, $2\ R = 0.21$ cm (similar to a of Fig. 3), suspended in a solution of $ZnCl_2$, the following results were found: (a) When the long side is oriented parallel to the current, $F = 41.0$ dynes; (b) when the long side is oriented parallel to the magnetic field, $F = 0$. Force computed for a metal sphere of this volume, $F = 3.88$ dynes.

We see that the force in case (a) greatly exceeds the force upon a sphere of equal volume, whereas in case (b) it vanishes. The cylinder experiences a torque orienting its axis parallel to the magnetic field, about which it persistently oscillates.

Similar experiments were carried out with dielectric disks and cylinders. Table 2 illustrates the behavior of a disk and of a cylinder at $H = 1857$ oersteds and $j = 0.146$ amp/cm^2.

Table 2 shows that, for certain orientations of the cylinder and of the disk, the force is the same as upon a sphere of equal volume, whereas for others the discrepancy may be quite large, as indicated most strikingly by data on the last line.

The dependence of the force upon the shape and orientation is of importance in considering migration of nonspherical bodies. Such bodies tend to be oriented $\parallel H$ or $\perp H$ in a liquid even at $j = 0$ if their magnetic permeability differs from that of the liquid medium. In addition, we have the orienting torque referred to above at $j \neq 0$.

Use of alternating fields. In order to avoid undesirable electrochemical reactions at the electrodes and at the interface between the solution and the suspended particles, alternating currents have been used in conjunction with an alternating magnetic field. It is desirable that the current be as nearly as possible in phase with the magnetic field. In this case the force will not reverse direction as the magnetic field and the current do so. A reversal of the phase of the current or of the field reverses the direction of migration of the particles.

Some possible uses of this effect. Among the possible applications of this effect might be mentioned the separation of particles of nearly equal density but distinctly different electrical conductivity; for instance, cells of different tissues, algae, bacteria, and possibly viruses. In the case of two kinds of cells of different conductivity, by adjusting the conductivity of the surrounding fluid to an intermediate value, the two species can be made to migrate in opposite directions. Particles of different shapes (e.g., spherules, rodlets, and platelets) may be separated even when their densities, volumes, and electrical conductivities are the same.

The electrical conductivity of irregular bodies and of microscopic particles may be measured by finding the conductivity of a solution in which they experience no electromagnetic force. This offers the possibility of measuring the electrical conductivity of various tissues and of isolated living cells. The electrical stimulation of the cells could be avoided by using alternating fields and currents of sufficiently high frequency.[6] Such observations of variation in the electrical conductivity of active cells would be of interest in studies of changes in cell membrane permeability in response to various stimuli. Similar electromagnetic forces should be observable in high-frequency electromagnetic fields with suspensions in dielectric media.

Manuscript received June 26, 1952.

[6] The use of high frequencies would also be desirable for the purpose of minimizing cell membrane impedance in measurements of the cell resistance.

Intra-Ocular Hemorrhagic Reaction Induced by Ectoplacental Trophoblast in Hypophysectomized Mice

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Tubal eggs, whole blastocysts, or isolated ectoplacental trophoblast of the mouse will produce a vigorous hemorrhagic reaction when implanted into the eyes of immature or adult animals of either sex (*1–3*). The occurrence of the reaction in immature and male animals indicates that it does not have the same hormonal requirements as the marked endometrial hyperemia occurring at the normal implantation site. The question may be asked, however, whether the reaction has some other hormonal background that would be disrupted by hypophysectomy.

The ectoplacental region of 8-day C × C3H mouse embryos (early somite stages) was implanted into the right eye of 18 hypophysectomized and 10 normal

C × C3H males. Hypophysectomy was performed at 8 weeks of age, and implants were made 6, 21, and 35 days later into groups of 8, 5, and 5 hypophysectomized and 5, 3, and 2 control animals, respectively. All animals were weighed on the day of hypophysectomy and weekly thereafter. Operated animals lost approximately 15% of their weight during the first week. Subsequently, their weight appeared to stabilize for 2 weeks and then declined slowly for the remainder of the experimental period. Total extirpation of the pituitary gland was achieved in all operated mice, as ascertained by visual inspection (× 9 magnification) of the sella turcica and adjacent tissues, and by body weight data on individual animals.

The reactions of operated and control groups to the trophoblast implant were indistinguishable. In all groups intra-ocular hemorrhage appeared by 48 hr, and the reaction continued to what has been characterized as the ++ level; i.e. the whole eye became dark-red and protuberant, frequently rupturing at the incision site. In animals held longer than 7–10 days the reaction appeared to regress as previously described (*3*).

It is concluded that the intra-ocular hemorrhagic reaction to ectoplacental trophoblast in the mouse is independent not only of the particular hormonal conditions occurring in the female at the time of normal implantation but, since it occurs in full strength in animals 35 days after hypophysectomy, is independent of all hormonal background dependent upon pituitary function.

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Manuscript received July 23, 1952.

Amino Acid Content of Dehydrated Giant African Snails (*Achatina fulica* Bowdich)[1]

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As a part of a plan to make a constructive approach to the serious problem of the giant African snail (*Achatina fulica* Bowdich) in the islands of the Pacific, assays of the essential amino acids were made to determine the possibility of using "snail meal" as a source of animal protein in the feeds of poultry and livestock. To our knowledge, no other tests of this nature have been made on this molluscan pest, although van Weel (*1*), and more recently Garnadi (*2*), have made tests to determine percentages of some of the basic chemical constituents.

The snails were collected alive in the field and submerged in boiling water just long enough to remove the soft parts from the shell. The carcasses were then dehydrated at moderate temperatures and reduced to a fine meal or powder in a Wiley mill. Amino acid assays of this meal were made by procedures previously reported by Kemmerer and Acosta (*3*).[2] The results of these assays are given in Table 1, with the percentages of the amino acids being shown in terms of both the snail meal sample and the total protein content of the snail meal. Unfortunately, samples were not large enough in Lots C and D to determine percentages of threonine and tryptophan.

TABLE 1

Amino Acid Content of Giant African Snail

Protein content	Lot C		Lot D		Lot E	
	69.9		64.9		61.6	
Amino acid	%, Sample basis	%, Protein basis	%, Sample basis	%, Protein basis	%, Sample basis	%, Protein basis
Arginine	6.46	9.24	8.60	13.25	4.07	6.61
Histidine	0.96	1.38	1.02	1.57	0.99	1.62
Isoleucine	3.15	4.51	3.65	5.62	2.83	4.59
Leucine	3.43	4.91	3.77	5.81	4.64	7.53
Lysine	5.97	8.54	6.48	9.98	3.45	5.60
Methionine	0.70	0.99	0.84	1.29	0.72	1.17
Phenylalanine	2.58	3.69	2.24	3.44	2.43	3.94
Threonine	No values		No values		2.65	4.30
Tryptophan	"	"	"	"	0.38	0.61
Valine	2.97	4.25	3.16	4.87	3.18	5.16

It will be seen that the values of Lots C and D compare quite favorably. In Lot E, however, three of the amino acids show significant departures in their values—viz., arginine, leucine, and lysine. Several factors may enter into a possible explanation of these differences. Specimens in Lot E were collected in Kaneohe, Hawaii, by Philip W. Weber, of the Board of Agriculture, in April 1952 and kept in close confinement for a number of days without food or water. Snails kept under such conditions will very often suffer dietary deficiencies which may possibly be reflected in alterations in the normal basic values of constituent amino acids. Unfortunately, the paucity of research work in the metabolism of terrestrial gastropods does not permit us to determine whether possible starvation or malnutrition could effect a reduction in the levels of arginine and lysine and an increase in leucine. Specimens in Lots C and D, on the other hand, were collected in the Palau Islands (Ngarmalk Island and Ngerebeched, Koror Island, respectively) by Peter J. R Hill in April 1950 and were killed and dehydrated as quickly as possible. Dehydration was accomplished in an improvised plant dryer at a temperature, maintained by a large electric light bulb, held close to 160° F. Yoshio Kondo, of the Bishop Museum, dehydrated the Hawaiian specimens

[1] This work has been supported in part by a grant-in-aid from the Sigma Xi–Resa Research Fund.

[2] Grateful acknowledgment is made to Judith Heimann, who made these determinations.

at a slower rate and at lower temperatures through the alternate use of sunlight and an improvised electric plate oven.

Because any difference in the environment will be reflected in the food and therefore the nutrition, this fact will continue to remain as a possible explanation for the differences between the lots from Hawaii and the Palau Islands.

At the height of reproductive activity, the albumen gland of the female conduit in these hermaphroditic animals may become so large that it actually exceeds the size of the liver or digestive gland. Because of the proteinaceous nature of albumen, the hypertrophy of this gland is almost certain to produce changes in the amino acid ratios.

A comparison of the values for Lot D with those of Dunn (*4*) indicates that arginine is nearly 2⅓ and lysine over 1⅓ times the amounts in whole egg. All other values, although appreciable and significant, fall below the values for whole egg. Similar analysis of cottonseed meal (*5*) shows that its value as a poultry and livestock feed is limited, as is almost universally the case with many other vegetable products, because of the deficiency of the very essential amino acid, lysine. The immediate inference is that this deficiency could be overcome through the addition of snail meal. Tests designed to determine both the effectiveness of this combination and the growth adequacy factors of snail meal alone are currently being set up through the use of controlled chick feeding experiments at the University of Arizona. It is expected that the results of these tests, along with additional amino acid assays, will be announced at an early date.

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Manuscript received July 21, 1952.

Influence of Peripheral Cholinergic Blocking Drugs on Survival Time in X-Ray Irradiated Mice[1]

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In 1949 Larkin (*1*) reported that atropine increased the survival time in x-ray irradiated mice. It was difficult, however, to understand how a dose of 0.65 mg/kg of atropine could possibly produce sufficient cholinergic blockade to influence the survival time in irradiated animals. Furthermore, if such a small nontoxic dose of atropine could favorably influence irradiation survival time, doses two and three times that amount should prove even more beneficial, because they would have a tendency to increase the effective cholinergic blockade while still remaining in the nontoxic range. Other cholinergic blocking drugs less toxic than, and almost as potent as, atropine should also prove beneficial under the above conditions.

Male CF1 strain mice, weighing an average of 20 g each, were arranged in groups of 20 animals each. Except during irradiation, the animals were maintained in an air-conditioned room at 72° ± 5° F and were given a diet of Rockland pellets supplemented weekly with additional vitamins A and D. Beginning 1 day prior to irradiation and continuing until 90–100% of the animals had died (10–16 days), each animal received daily by intramuscular injection a constant volume of 0.1 ml of the following concentrations of peripheral cholinergic blocking drugs: Group I, 0.45×10^{-3} *M*; Group II, 0.90×10^{-3} *M*; Group III, 1.35×10^{-3} *M*. The controls received 0.9% saline. The drugs used were atropine, Merck MK-02 (tropine benzhydrylether methane sulfate); Win-2299 (1-methyl-3-piperidyl-methyl-phenyl-2-thienyl acetate); and Bentyl (1-cyclohexylhexahydrobenzoic acid, β-diethylaminoethyl ester). The injections were given in alternate thighs. The 550-r radiation dose was administered from above and below the mice with two 250 kvp Picker Industrial Units operating simultaneously. The technical factors were: 250 kvp; 15 ma; FOD 100 cm, filters, 0.21 mm Cu inherent, 0.5 mm Cu parabolic, and 1.0 mm Al; HVL 2.02; size of field —total body, r/min measured in air 17.2–18.4. Both units were calibrated prior to each experiment with a Victoreen thimble r-meter. The animals were restrained in a plastic cage similar to the one previously described for guinea pigs (*2*). The results obtained were analyzed statistically by the method of Litchfield (*3*).

The results obtained with the four drugs are given in Table 1. From the data it is evident that none of the drugs had a significant effect on total mortality. Furthermore, the response of the animals to the radiation dosage was remarkably constant over the 8 months during which the experiments were conducted. This is borne out by the total mortality figures, as well as by the slopes of the time-percentage effect curves. Statistical analysis of the reaction time ratios shows that all concentrations of MK-02, the 0.90×10^{-3} M concentration of Win-2299, and the 0.45 and 0.90×10^{-3} *M* concentrations of Bentyl significantly affected the survival time of the mice in a favorable manner. From a practical viewpoint, however, the over-all differences between the ST_{50} day and the day on which 90–100% of the mice were dead are so small that such medication cannot be considered highly beneficial in counteracting over-all radiation injury, but it

[1] This article is based on work performed under Contract No. AT-04-1-GEN-12 between the Atomic Energy Commission and the University of California, Los Angeles.

[2] The authors wish to thank Merck & Co. for the MK-02, M. L. Tainter for the Win-2299, and Harold Werner for the Bentyl used in this study.

TABLE 1

EFFECT OF CHOLINERGIC BLOCKERS ON SURVIVAL TIME IN IRRADIATED MICE

Drug	Concentration $\times 10^{-3}$ M	ST_{20}* and range in days	Slope and range	Total mortality	
				Day	Percentage
Saline	—	9.1 (8.4– 9.9)	1.21 (1.14–1.29)	13	90
	0.45	9.1 (8.4– 9.9)	1.21 (1.14–1.29)	12	100
Atropine	0.90	9.1 (8.4– 9.9)	1.21 (1.14–1.29)	12	100
	1.35	9.1 (8.4– 9.9)	1.21 (1.14–1.29)	14	100
Saline	—	7.0 (6.4– 7.7)	1.25 (1.16–1.33)	10	100
	0.45	10.2 (9.6–10.9)	1.15 (1.10–1.20)	11	100
MK-02	0.90	10.7 (9.8–11.6)	1.22 (1.14–1.29)	13	90
	1.35	10.7 (9.8–11.6)	1.22 (1.14–1.29)	16	90
Saline	—	7.9 (6.5– 7.6)	1.20 (1.13–1.27)	10	100
	0.45	8.3 (7.6– 8.9)	1.20 (1.13–1.27)	12	100
Win-2299	0.90	10.3 (10.0–10.6)	1.07 (1.04–1.09)	12	100
	1.35	8.2 (7.6– 8.9)	1.20 (1.13–1.27)	12	100
Saline	—	5.3 (4.7– 6.0)	1.32 (1.21–1.44)	10	100
	0.45	8.3 (7.4– 9.3)	1.29 (1.18–1.40)	13	100
Bentyl	0.90	8.7 (7.9– 9.5)	1.24 (1.16–1.33)	12	95
	1.35	6.1 (5.1– 7.2)	1.50 (1.30–1.70)	11	100

* ST_{20} = day on which 50% of animals are alive. Values are at odds of 19/20.

might be useful in the preliminary phase of the syndrome.

There is no general agreement concerning the part played by the cholinergic branch of the autonomic nervous system in the radiation syndrome. Burnett, Burke, and Upton (*4*) showed that cogeners of acetylcholine protected C_{57} strain mice from the lethal effects of x-irradiation and that atropine could negate such protectant action. On the other hand, Larkin (*1*) reported that atropine increased survival time in CF1 strain mice, although it did not affect the total mortality caused by such irradiation. The results herein reported show that atropine does not increase survival time in x-irradiated CF1 strain mice. Other related synthetic drugs, however (MK-02, Win-2299, and Bentyl), which have been shown to have equivalent *in vitro* antispasmodic poteney and to be less toxic than atropine (*5–7*) do increase survival time but have no effect on total mortality. We have no explanation for the ineffectiveness of atropine, because *in vivo* this drug should have been as active as the other antispasmodics employed.

Analysis of the mechanism(s) involved in the so-called protectant effect of antispasmodic drugs must be based upon present knowledge of the actions of ionizing radiation on the animal organism. Quastler *et al.* (*8*) have shown that the early deaths from ionizing radiation in mice are due to intestinal damage. Conard (*9*) showed that drugs that inhibit acetylcholine inhibit x-ray response, and drugs that augment the action of acetylcholine also augment the x-ray response. Burn *et al.* (*10*) have observed that loops of intestine obtained from x-irradiated rats are more sensitive to acetylcholine 1–2 days postirradiation. There is also a concomitant fall in the "pseudo" but not in the "true" cholinesterase content of the intestine at the same time. Upon the basis of these reports it seems probable that the increase in survival time may be the result of peripheral cholinergic blockade decreasing intestinal actitvity and thus decreasing intestinal trauma that might result from active propulsive movements of the intestinal contents. Although intestinal relaxation by the antispasmodies might decrease intestinal damage, these drugs would not affect the bacterial and hemorrhagic phases of the radiation syndrome and thus would not decrease the mortality caused by these factors. The results herein presented, with the exception of those with atropine, would tend to support such a hypothesis and would indicate that the approach to radiation injury therapeutics should be a multiple one designed to combat successive phases of the radiation syndrome.

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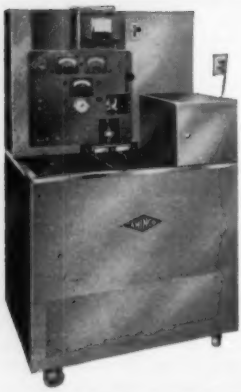

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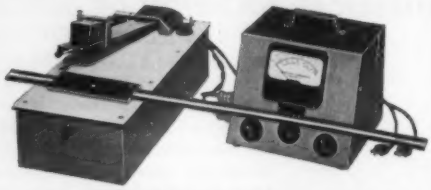

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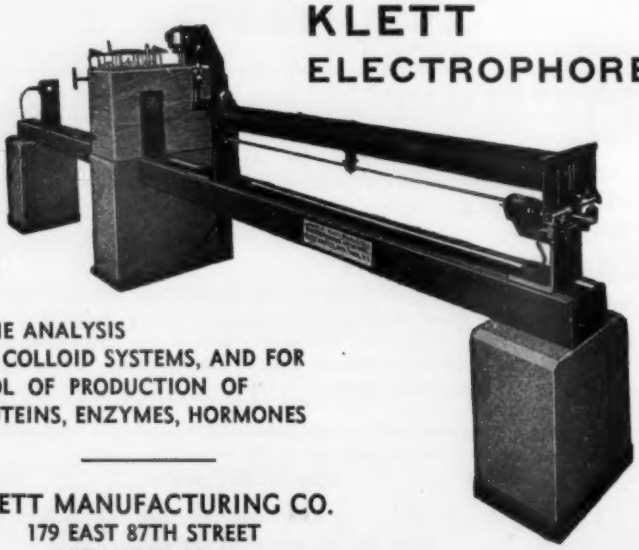

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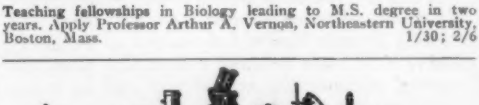

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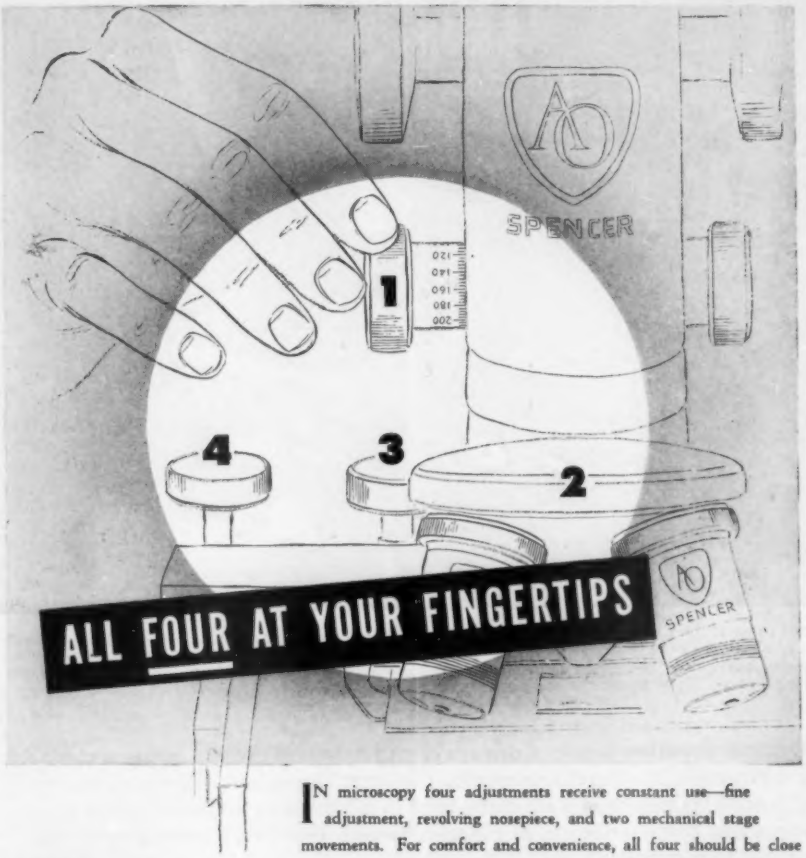

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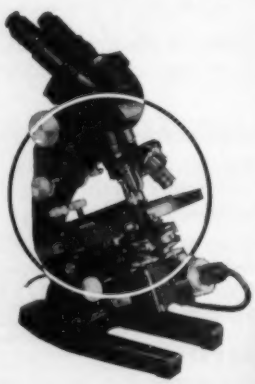

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